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THE POWER AND LIMITS OF SCIENCE

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A Philosophical Study

by

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LONDON

CHAPMAN & HALL LTD.

37 ESSEX STREET, W.C.2

1949

First published 1949

Catalogue No. 399/4

PRINTED IN GREAT BRITAIN BY
JARROLD AND SONS LTD., NORWICH

To all who have taught me,
and first of all to my parents,
this book is gratefully dedicated.

Preface

THIS book has been written to put before the reader a view of science, and its relation to other forms of knowledge, based on a study of its method (Chapters I to VII); and to sketch a view of the place of science in life, corresponding to this estimate of its place in thought (Chapters VIII to XI).

To-day our ears are filled with praise of the achievements of science, and far-reaching claims are made for scientific knowledge, with few dissentient voices. It is strange, however, that men do not more often examine the method of science, its field of work and point of view, in order to see what kind of knowledge it can in principle give us, and whether we must consult other sources. It is time that scientists applied themselves more seriously to such questions as 'Is science the only reliable road to knowledge?' and 'Can science tell us all we need to know?' The prestige of science to-day is very great; scientists have therefore a certain responsibility to consider carefully the scope and limitations of their professional activities.

Any one of my chapters raises questions that need a lifetime's study. But I recall the saying that the desire to write the perfect book has prevented the publication of many useful ones; and would ask the specialists, into whose fields I have trespassed, to bear with my haste, and, if they will, to answer, better than I have been able to, these extremely important questions. For answered they must be, if we are to make any progress towards a new synthesis, so badly needed, in which the place of science, as a means of investigation and as an element in civilised life, is accurately defined.

It is pleasant to acknowledge gratefully the help of many friends, whose comments have greatly improved the text; and especially of Dr. F. Sherwood Taylor, without whose encouragement the book would not have been started, and of my wife, without whose help it would not have been finished. My thanks are also due to the editors of the following periodicals in which various parts of the text have appeared: *The Times Educational Supplement; Endeavour; Blackfriars; The Wind and the Rain.*

E. F. C.

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PART ONE

Introductory

CHAPTER I

Science in its Setting

CIVILISATION AND THE RISE OF SCIENCE

IT is by now sufficiently notorious that we live at a crisis in Western civilisation. The crisis is variously interpreted, but in many people's judgment science has something to do with it. According to some, science has wrought our ruin, because it has given mankind the power to destroy itself. According to others, science will work our salvation, because it is only another name for reason, and if we drop our outworn modes of thought we can use it to build a new metaphysic, a new ethic, a new art and a new religion. According to others again, science can put an end to want, and if we abolish want we shall abolish also hatred, envy and avarice; therefore, they say, we need science for both the physical and moral health of society.

Such diagnoses, crude as they are in their identification of science with technology and in their estimate of its capabilities, contain at least this much truth. Western civilisation has been immensely affected both mentally and materially by the forces that claim their origin from the advance of science since the time of Galileo. On the one hand, industry has based itself on specialised technical knowledge, which in turn relies upon science. And industrialisation has vastly altered the machinery of living, the material background of life; for instance, it has brought about great changes in transport, communications, health services and entertainment in the last hundred years, and there is no reason to think we have reached the end of them; the possibility of controlling disease, food production, even weather, seems considerably less remote to-day than when Wells wrote his scientific romances. Technical invention has, moreover, devised methods by which a relatively small band of determined men can exterminate whole populations. Such techniques could not be devised without a

scientific understanding of nature. Science and scientists have thus become of great importance to industrial societies—though indirectly and at one remove, via technology. On the other hand, the success of science in interpreting nature has struck very forcibly the imagination of Western man, especially since the work of men like Darwin, Freud and Pavlov began to extend it to living things and even mental life. At a time when philosophers and theologians have fallen into disrepute with the general public, the successes of science in its own field are so impressive that many have been led to suppose that all departments of thought would benefit by the same approach—that it is only a matter of time before science will settle finally the great questions that men have always asked about life. Because of these two influences—one material, the other mental—science was never in higher repute than it is to-day; and this at a time when the prestige of most branches of pure learning is perhaps lower than it has been for centuries. Many people think that science will not only lead them to a material paradise but will answer all their questions as well. They regard science not only as the cure for want and pain, but as the method of thought *par excellence*, the one great source of truth.

Historians may well conclude that many of the traits that distinguish the present phase of Western civilisation from those that preceded it are traceable ultimately to these influences derived (whether legitimately or not) from science. It is a commonplace of history that in the best of European culture three great strands can be discerned. One is the zest for understanding and intellectual discovery, for the things of the mind, for truth and beauty, that we derive from the classical age of Greece. A second is the ideal of a settled and law-abiding society, with stable institutions and administration, that we derive from the Roman civilisation. The third is the new light on man's nature and destiny, the new respect for personality, the new ideals of thought and conduct, the new valuation, too, of both intellect and law, that we owe to the Christian revelation. Respect for truth, concern for justice, reverence for the human person—these have been the major elements in the mental climate of educated Europeans since the

Middle Ages. But in the last hundred years they have been much modified, at least in the popular estimation, by influences claiming natural science as their inspiration. Discovery and understanding have been thought of more and more as the prerogatives of science; philosophy and theology dismissed as moonshine. Our conception of man has been more and more affected by the materialist account of him; we plan for his health and wealth, rather than for his liberty and virtue; doctor's orders, not the sermon on the mount, are our rule of life. Our conception of society has correspondingly hardened; we tend to identify the community with the state, and in place of variety with inequality we tend to uniformity imposed by compulsion; governments begin to claim omnipotence—and technology has given them the power to enforce the claim. No doubt there have been other influences at work, but at least a considerable share in effecting these changes in outlook may be attributed to the two great currents claiming science as their origin—industrial technology and the belief in the unlimited applicability of scientific method.

FAITH IN SCIENCE

Anyone familiar with the currents of thought of this century is aware of the increasing faith in the universal scope of the scientific method, and in science as the way to all truth, that characterises a generation whose appreciation of other modes of thought has diminished. I have seen it advocated in respectable journals that science should take the place in education formerly occupied by classics; that we need a new code of ethics to be compiled by the scientific method; and that philosophy is nothing but ossified science. People uncertain about the nature of man and his situation and destiny turn for answers to physicists, biologists, psychologists and economists. The place occupied (speaking very generally) in the sixteenth century by dramatists like Shakespeare and Marlowe, in the seventeenth century by poets like Milton and divines like Jeremy Taylor, in the eighteenth century by philosophers, satirists and historians, and in the nineteenth century by novelists and poets, seems in the twentieth century to have

fallen to those who present science to the public. They would have us believe that natural science has important philosophical implications; that it can correct philosophers in their logic and ethics and metaphysics. An admirable summary of 'progressive' notions, Dr. Joad's *Guide to Modern Thought*, consists almost entirely of arguments drawn (or allegedly drawn) from physics, biology and psychology. Many people have been led to think that the procedure of natural science is the royal road to truth in every field, and that what cannot be proved by science cannot be true. This faith in science and its general applicability is one of the distinguishing characteristics of Western civilisation in our time.

I do not say that scientific knowledge itself is a distinctive mark of our time, or that the understanding of nature is the great preoccupation of our contemporaries; though no doubt genuine interest in science is much more widespread now than ever before. The new element that characterises so much modern thinking is not so much science, as an attitude towards science; not scientific method, but faith in the unlimited applicability of scientific method; not the conclusions of science, but faith in the relevance of science to every kind of problem.

Such a faith calls for examination. We ought to inspect carefully the credentials of a belief so much at variance with the Western tradition, in which philosophy, theology, history, law and literature have all sought truth in their own ways; in the light of a common tradition, indeed, but according to their own appropriate methods. Scientific method, one would have thought, was not the same thing as rational method, but rather was one particular version of it. But the scientific approach has not undergone the scrutiny that one would expect from the magnitude of the trust placed in it. Philosophers, indeed, have considered it, but their works are technical and their conclusions remain unfamiliar. My first object in this book, then, is to discuss the kind of knowledge that we can expect from natural science and the kind of conclusions that can legitimately be obtained from it. Clearly the kind of knowledge that it can give us depends on the kind of evidence it takes into account and the way it interprets

that evidence; that is, it depends on the character of scientific method. By the examination of this method we may hope to learn whether science can give us answers to all our questions, or whether ultimately we must turn elsewhere.

ON RATIONAL METHODS IN GENERAL

By rational methods I mean the methods of reason working on the data of experience. We have different kinds of experience, which constitute different kinds of evidence about the world; and reason can deal in different ways with this evidence. In any rational examination of the world, the kind of results obtainable depends upon the method of investigation. For instance, the method of physics relies upon measurement, and so physical knowledge is sure to be about quantities. The method of course is not arbitrary; it is determined by two factors: (i) the subject-matter under investigation and (ii) the point of view from which it is investigated. The two are not the same, as we can see by considering as an illustration the study of history; in an historical investigation we may examine a given episode from various aspects—economic, political, legal, and so on; the subject-matter or the field of work, and the point of view or aspect of investigation, are both relevant to the results. In a somewhat similar way, we can consider a given object, a man, for instance, from the points of view of different sciences—psychology, biology, physics, and so on; as well as from philosophical points of view such as that of ethics. Again we can consider objects of different kinds—a man, say, or a tree, or a stone—from the same point of view, that of physics. The kind of object about which knowledge is sought, and the angle from which it is sought, point forward to the method that must be used; and the method in turn points forward to the type of knowledge that may be expected. To anticipate the next chapter a little for the sake of giving an example: the subject-matter of physics is inanimate matter; the point of view is quantitative; the method accordingly is measurement, and this determines the kind of conclusions attainable. Analogous considerations must apply to rational method in other studies. By examining the

method of a particular science, we may elucidate the status of the conclusions that may be drawn from it. Further, it should be possible, by examining scientific method in general, to discover the nature and limits of the knowledge obtainable by natural science as a whole. This will help us to answer the question whether we need other methods to supplement scientific knowledge; whether there are valid points of view other than that of natural science, and subject-matters in which it is not competent.

THE METHOD OF SCIENCE

Our procedure in the first part of this book is to observe the actual methods of science. Working forwards, we can then deduce the kind of knowledge that can be expected from science, and 'place' it in the body of knowledge generally; working backwards, we can the more easily see what are the subject-matter and point of view of science, to suit which the method was developed. I propose in the first place to take my examples from the methods of physical science—physics and chemistry and their derivatives. Biological and psychological sciences would need a modified treatment; I am not sure that the conclusions would be markedly different, but the point is here unimportant, for the following reason. Our conclusions about the status of natural science in general will be drawn from a consideration of the method common to all natural sciences, namely inductive argument; we shall have to lay bare and examine the presuppositions of inductive method, the propositions whose truth is a condition of the validity of induction, and which are therefore of great importance for the status of scientific knowledge and the relation of science to philosophy. But let us begin with the rather easier task of examining the method of physics.

CHAPTER II

The Method of Physics

IN this chapter I shall try to say what kind of information we can expect from physics (with which I include chemistry). As was said in Chapter I, this depends on the method of physics, whose method depends, in turn, on its subject-matter and its point of view. The world is very various and complex, and the method of physics, so far from being the one and universal rational way of approaching reality, is a specialised method which leaves aside a great deal of our experience. What is the type of evidence concerned in physical investigations, and how is this evidence obtained?

PRELIMINARY CLASSIFICATION: PHYSICS STUDIES INANIMATE MATTER

All science depends upon a preliminary common-sense sorting of the events and things that we come upon in experience. We compare things and their occurrences, and note their differences. For instance, we find that man is rational, because he can draw from experience ideas or concepts, follow an argument, form generalisations, direct his life by principles, recognise duties, and in general think and behave rationally. But no one supposes that a horse can reflect upon the Common Law or solve the simplest problem in algebra. The man differs from the horse because he is rational. Again, a live horse differs from the wooden horse of Troy, not so much in shape or size as because (as we say for short) the live horse is an organism. His heart and brain and limbs do not behave as if they were independent beings, but co-operate for the overriding purposes of the whole. Again, the live horse has intricate equipment for repairing damage, for counteracting the effects of changes in his environment, for normal maintenance of life, and for reproduction. The wooden horse, on the other hand,

is not in the same sense a whole; it is a mere aggregate, held together not spontaneously but by means of nails; it has no inner principle of unity, none of the characteristics of an organism. We recognise, then, beings at three levels: rational, animate and inanimate. Matter forms part of beings of each kind, but it is in three different situations. In the organism, matter is subject not only to the laws of inanimate matter but to the overriding law that the parts of an organism subserve the good of the whole. In a man the bodily organism itself is subject also to the control of reason. Later on we shall meet various alleged objections to these conclusions of common sense. At present we merely note that this preliminary classification is essential to the natural sciences, because the different types of being give rise to different sciences. Physics and chemistry deal with inanimate matter. Organisms are dealt with by various biological sciences; some are more concerned with the organism as such, some more with the operation of physical laws in organisms. Psychological sciences, properly so called, deal with that region, peculiar to the human organism, where mind and body are both concerned—the passions, the emotions, perception, temperament. The special characteristics of man as a rational being belong to the branches of philosophy: logic, the science of thought; theory of knowledge, the criticism of experience; metaphysics, the interpretation of experience in general; morals, the principles of the good life; aesthetics, the study of the beautiful in art and nature.

Physics begins, then, by ignoring all the characteristic properties of organisms and of human beings. It is concerned with inanimate matter.

GENERAL LAWS OF BEHAVIOUR OF INANIMATE MATTER

The next point is that physics is concerned with general laws. It is not interested in individual events as such. It is true that some unique occurrence, such as an eclipse, might conceivably be of physical interest, but only in so far as it exemplified general laws. Physics is concerned with events following one another according to a general rule, in invariable sequence (such as the

cooling and freezing of water); or events always occurring together (such as the heating of an axle by friction when it rotates); or with properties found always together in invariable association (such as the lustre of metals and their high electrical conductivity, or indeed the properties of any definite and stable chemical substance, whether element or compound).

Empirical regularities of this kind are first conceived at a common-sense level by reflecting on experience—a second stage of sorting. It is the work of this stage to pick out from the flux of phenomena 'systems' worth detailed examination—gases, for instance, or magnets, or pure chemical compounds. This is extremely important in the development of a young science, because it is easy to get such qualitative conceptions wrong, and for the error to go undetected for a long time. We must not imagine that the fundamental generalisations on which modern physics is built are self-evident. For instance, it was for long believed that there was a relation between the speed of a falling body and its mass; modern dynamics did not begin until this belief was corrected. That the same dynamical laws apply to terrestrial and celestial bodies was likewise unsuspected for many centuries; a sharp distinction was drawn between celestial and sublunary bodies, and did not break down until the invention of the telescope. This stage of qualitative classification must consequently be considered also in the theory of induction. For no chain of reasoning is stronger than its weakest link, and these fundamental generalisations, such as 'there is a kind of gas called hydrogen whose properties in every instance are the same', are essential links in inductive reasoning. We shall see that the theory of induction pays special attention to this very elementary stage of science.

As the science develops, and the empirical laws begin to be linked up by theories, errors in them become much less likely, and at the present stage of physics a single experiment is commonly enough to settle whether a particular law holds or not. We shall return to this point. For the present we note that physics is concerned with the general laws discernible in the behaviour of

inanimate matter. The word 'law', incidentally, is perhaps unfortunate. It suggests that matter *must* behave in such and such a way; whereas all we are entitled to say is that in the past, on the relatively few occasions on which we observed it, it *did* behave in that way. One instance to the contrary will upset a law, and so it must always be regarded as tentative and provisional.

To take a concrete example, physics must give some account of the general laws of the behaviour of air. At the common-sense level that we have reached so far, an example of such a general law would be the generalisation that if the pressure on air be increased the volume will decrease. If we close the outlet of a bicycle pump and press on the plunger, the air in the pump contracts; when we stop pressing, it expands again. We can repeat the procedure as often as we like; and the result is found to be independent of the material and dimensions of the pump, the phase of the moon, the height of the sun . . . and indeed of most other factors, except the temperature. These notions may seem obvious to us now but they were not obvious much before the experiments of Robert Boyle in the seventeenth century on the 'spring of the air'; and if we are to understand the method of a developed science we must examine the humble generalisations that it presupposes. The behaviour of air, then, has provided us with a generalisation worth pursuing at the next higher level, now to be considered.

PHYSICS ESSENTIALLY QUANTITATIVE: MEASUREMENT

Still considering the actual method and procedure of physical science, the most striking fact next to be mentioned is that it is concerned with what can be *measured.* It is essentially quantitative. This does not mean that qualities are unimportant in physical observation; for one can carry out a quantitative comparison of two objects only in respect of some quality that they both possess. Recognition of qualities is therefore a part of physical investigation, and correct classification is its first step. But physics is not content with classification. Confronted by any of the systems classified by common sense, it sets to work measuring their characteristics.

Measurement means that as a result of observation we assign a numerical value to some property of a system. Sometimes this can be done by direct comparison with a standard or unit; for instance, we lay a metre rule alongside an object and assign a numerical value to its length, in terms of the unit of length (the metre or centimetre). How is it that we are able thus to represent lengths by numbers—which, on the face of it, are quite different from lengths—and what properties can we expect to be directly measurable in this way? It seems that the reason why lengths can be directly measured is that they are *analogous* to numbers, in respect of their additive properties. A set of bodies of unit length (say, a set of bars one centimetre long) can be combined additively, by placing end to end, so as to match a body of any given length; this property is analogous to the additivity of the cardinal numbers (1, 2, 3, etc.) in virtue of which we can arrive at any given number by successive addition of units; in fact, the rules for combining bodies of unit length, to match a body of given length, are analogous to the rules for adding numbers to equal a given number. The length of an object is directly measurable, then, because a numerical value can be assigned to it by counting the number of standard units which when suitably combined (by juxtaposing) will match the given object in respect of length. The mass of a body, also, is directly measurable, for the same reason—mass has the necessary analogy with number, in that bodies constituting units of mass can be combined additively to match a body of any given mass; by means of the balance we can count directly the number of units which, when combined, match a given object in respect of mass. (Measurement of mass may also be reduced to measurements of length by using some device such as a steelyard.) Time intervals also can be directly measured; the time between two events can be matched by a succession of standard intervals, such as those given by the swings of a pendulum, which can be counted. (Measurements of time may be reduced to measurements of length, or pointer-readings, by using a clock.) Counting, then, is the fundamental operation in physics, leading to numerical values for measurable properties.

The directly measurable properties are length, mass and time. Other measurables used in physics, such as velocity or energy or electric charge, are convenient algebraic combinations of these; accordingly they can be measured indirectly by their relation to quantities directly measurable, and so ultimately to certain lengths or numbers. Thus velocity may be expressed in terms of length and time, acceleration in terms of velocity and time, force in terms of mass and acceleration, and energy in terms of force and distance. Electric charges and magnetic poles are measured in terms of the forces and distances between them. And so it is with all the 'derived' quantities of physics.

Our qualitative view of the 'spring of the air' would now be expected to give place to a quantitative view. In physics the qualitative notion of pushing on the pump handle and contraction or expansion of the air will have to be replaced by quantitative aspects of those occurrences. The first is replaced by the concept of pressure (expressible as force per unit area), and the second by that of volume. Then our generalisation about air takes the form: 'If the pressure on air is increased, the volume decreases'.

QUANTITATIVE LAWS

Measurement is not an end in itself for physics. Physics is concerned with laws, and it is the laws relating measured quantities that are of interest to it. Quantities are measured in order to find correlations between them, to investigate the laws of their concomitant variation. Qualitative generalisations are not enough; in physics they must be replaced by relations between measured quantities, or, more accurately, between the numbers that represent them—for example, between the numerical values of the pressure and volume of air. Everyone knows the simple law, discovered by Boyle: the volume of a mass of air is inversely proportional to the pressure other things being equal. But let us look more closely at the way in which such a law is reached.

We first set up an experimental arrangement by which we can measure variations in pressure and volume. Suppose we use a vertical cylinder with a tightly fitting piston—like a bicycle pump

on end with its exit closed. (Let us suppose that friction and leakage are negligible.) We can alter the pressure by putting weights on the top of the piston-rod; the total weight divided by the area is a measure of the pressure. We can measure the change of volume by measuring the movement of the piston-rod. We try a series of pressures, and measure the volume corresponding to each. We obtain at each observation a pair of numbers, one representing pressure, the other volume. Can we find a general relation between these variables? We try to correlate the observed values. To do this we try various functions of pressure and volume until we find one that is nearly fitted by all the pairs of numbers representing the measured pressures and volumes. This function turns out to be $pv=c$, where p stands for the numbers representing the measured pressures, and v stands for the numbers representing the measured volumes, and c is a constant. This equation, $pv=c$, is said to be an empirical law derived from observed data. The method by which the evidence for it is obtained is the method of concomitant variation.

STATUS OF QUANTITATIVE EMPIRICAL LAWS

But what precisely is the relation between the law and the evidence? Clearly the law does not simply re-state the contents of a table of corresponding values of p and v. In the first place, none of the pairs of values fits the relation *exactly*. We ascribe this to 'experimental error', and we recognise that every such measured value is uncertain by reason of experimental difficulties and sheer limitations of the senses. The art of experimental work consists largely in reducing these uncertainties. But they never disappear entirely. In physical science there is no exact 'correct answer'; a measurement can only be given as correct within certain limits, however small. We might, then, more accurately write our empirical law as: $pv=c\pm x$, where x represents the limits of variation of the product of the experimental values of p and v. But there is also a more serious consideration. When we formulate a law in the form of an equation like $pv=c$, we are asserting that the law holds for any pair of values of p and v whatever (between

the maximum and minimum used in the experiment). We assert a functional relation, holding for all relevant values of p and v. But we have only examined a few pairs of values. We have, then, asserted a physical law on the basis of a few instances. On the face of it, this is a most high-handed proceeding. If we find that in one observed instance p_1 is nearly equal to c/v_1, and that in another instance p_2 is nearly equal to c/v_2, and so on for a few more cases, we cheerfully formulate the law $p=c/v$, or $pv=c$, meaning that any value of p (between the limits used in the experiment) is nearly equal to c/v. The number of possible values of p is indefinitely large, and we have only examined a few of them, yet we make no bones about generalising from these few.

This simple example may suffice to call attention to the place of generalisation in physics.[1] An experimental law is not in general a bare summary of the experimental data; it is not a shorthand version of them. It is not simply a statement of something common to them. It cannot be deduced from them; by no process of deductive logic can a general equation be deduced from our particular observations. The empirical law is rather a *construction* from the data. It goes beyond the evidence; its does not so much express the results of observation as begin to interpret them.

Such generalising may be regarded as depending on an appeal to analogy. For it is analogy that suggests that, because the system is unaltered throughout the experiments except as regards pressure and volume, all possible values of the pressure and volume will very likely be connected by the same law as that found for a few values. If, in a series of states, the system is unchanged as regards mass, temperature and all other attributes, except volume and pressure, and if in some states it exhibits volumes and pressures that fit the relation $pv=c$, then we assume by analogy that it will exhibit the same law in other states. (The assumption in any argument from analogy is that if things are alike in some respects, there is some likelihood that they will be alike in other respects.)

But of what value exactly is an argument from analogy? In Shakespeare's *Henry the Fifth* we are not much impressed with

[1] We shall examine such generalisations more closely in Chapter IV.

Fluellen's reasoning by analogy when he compares Henry to Alexander the Great on the ground that there is a river at Monmouth and a river at Macedon, and salmons in both. We find Voltaire's argument rather weak, when he denies that coral is made by the insects found in it, on the ground that old cheese too is full of insects but no one supposes they made the cheese. Again, if Mr. X is known to be fat and stupid, and Mr. Y is known to be fat, it would be hazardous to wager that Mr. Y is also stupid. These are extreme examples, no doubt, but they serve to introduce two *caveats*. The first is that the conclusions of arguments by analogy have a certain likelihood, depending on the evidence; they are not certain. The second is that arguing by analogy is useless unless we have some independent reason for thinking that the analogy will (or may) hold. Only if we have independent grounds for thinking that *some* generalisation is true can we use analogy to suggest *which* generalisation is true. We must admit that when we believe that an empirical law will apply to a system in states that we have not observed, it is in virtue of a presupposition: we presuppose that there is a general law, describing the system in all states, and that all we have to do is to find it by examining a few typical states. Otherwise we should have no reason to suppose that the analogy we rely on would hold. Empirical laws, then, of the type formulated in physical investigation, depend not only on the data of observation, but on a belief that is *presupposed* by science and believed by scientists by virtue of their common sense: we can express it shortly as the assumption that there is order in nature. We shall return to this point later.

Our next step is a still more daring extrapolation. We have so far reached a generalisation about the behaviour of one specimen of air. We next assert that it is true of *all* specimens of air. We think this is justified, even though we have no intention of investigating every specimen of air; and we should be very surprised if any specimen exhibiting all the other known properties of air showed a different behaviour. Yet if we reflect, the step is a hazardous one. We are generalising from a very few specimens

of air to all specimens. The evidence hardly seems commensurate with the conclusion. The procedure obviously needs justifying; it is not self-evidently legitimate to pass thus from particular to general. As we shall see in Chapter IV, we rely here too upon the presupposition that anything which shows the other properties of air will show this property also; that there must be some general law and we have only to find it; in brief, that there is order in nature. Here we shall simply note the step and postpone the question of its justification.

Before we pass on to consider the theoretical interpretation of empirical laws, two further remarks on physical observation should be made.

EXPERIMENT AND OBSERVATION

In our example, a physical system was studied experimentally; one of the variables was controlled by the experimenter, and the values taken up by the other were measured. But sometimes neither of the variables can be controlled; as, for instance, when we seek to discover the relations between the motions and masses of the planets. In that case we have to be content with observation and to do without experiment. The status of the laws discovered is exactly the same. But the method of experiment is by far the more powerful and flexible method, for the following reason.

ISOLATION OF VARIABLES

When we measure the concomitant variation of two quantities in order to correlate them and find an empirical law connecting them, we must keep the system observed as free as possible from other variations. For instance, in correlating the pressure and volume of air, the variation which it is most important to eliminate is that of temperature. Many variations, such as those of the electric or magnetic fields, will exert negligible influences on the results, but the effect of the temperature is important. The temperature must therefore be kept, so far as possible, constant. The reason for this is evident: it is much harder to sort out the laws governing the simultaneous variation of several variables than

it is to find a single law expressing the variation of two of them. Moreover, we can see that the argument from analogy mentioned above is weakened if the system is not maintained in the same state, in all relevant respects, throughout a set of observations. Experiment allows us to control the independent variables, and so it is the most convenient and fruitful method of science.

THEORETICAL INTERPRETATION OF EMPIRICAL LAWS

Science, however, is not complete with the formulation of empirical laws. For though these express compactly the behaviour of physical systems they give us small understanding of them, and science is essentially directed towards the understanding of nature. (In this respect science differs from technology, which can rest content with accurate empirical laws, provided that they are adequate for the control and manipulation of matter for practical purposes.) It is sometimes said that science is concerned with the How of nature's workings, but not with the Why. This is an ambiguous statement, because there are various ways of answering the question 'Why?' To give the complete 'why' of the existence and behaviour of a thing is to state what sort of thing it is, what it is made of, who or what made it, and to what end; and an answer to any one of these questions is an answer 'why'. Now it is true that physical science does not deal with the question 'What is the end for which inanimate nature exists?' nor with the question 'Who made it?'—important though those questions and their answers are—and in that sense it does not tell us Why. But it does seek to answer, more fully than does a mere description of the behaviour of certain systems in certain situations, the question 'What sort of thing is inanimate nature—what can we understand about its structure?' This is the task of the theoretical interpretation of the empirical laws derived from observation. The observational part of science needs to be completed by the theoretical scheme, which seeks, in the old phrase, to 'save the phenomena'. That is, it seeks to formulate a model, or a conceptual scheme, to reproduce the observed behaviour of the system.

Thus, for instance, we have to interpret the empirical law that,

for a gas at constant temperature, $pv = c$. Can we imagine any model of a gas such that it would exhibit this law? Classical kinetic theory in its simplest form pictured the gas as a swarm of minute particles, hard and elastic, moving in all directions. These particles, according to the theory, collide with each other and with the walls of the vessel at intervals, and on these occasions behave exactly as billiard balls behave when they collide with each other or with the cushions; or, rather, as billiard balls would behave if they and the cushions were perfectly smooth and elastic, so that no energy were lost by friction. This behaviour is presumed to obey the same laws of mechanics as those found for ordinary bodies. The pressure of a gas on the vessel walls is then paralleled by the pressure due to the innumerable impacts of the particles on the walls of the enclosure. If we reduce the volume of the enclosure, the frequency of impact increases (because on the average a particle meets the wall more often) and so the pressure increases. Exact calculation by the methods of ordinary dynamics shows that for this model the product pv would indeed be a constant, just as we found by experiment for actual gases. (If we had sufficiently small and elastic billiard balls and cushions we could make a sort of two-dimensional mechanical model.) So far, then, the theoretical model is in accord with the observations. The gas behaves *as if* it consisted of hard elastic particles obeying the laws of Newtonian mechanics. But this alone would not be sufficient support for the theory. For it might be possible to devise many other models that would agree equally well with our observations. However, the pressure-volume relation is not the only one that this model can reproduce. For instance, if we assume that increase of temperature may be represented by increase in the average velocity of the particles, we find that we can deduce for the model a relation between temperature, pressure and volume that is very close to that found experimentally for gases. And many other properties of gases—diffusion, viscosity, and so on—are likewise quantitatively represented. The theoretical interpretation suggested does not agree merely with one observed property of the gas; it is in harmony with many observed properties

of very diverse kinds. One single model accounts for a variety of observations; many different experiments are unified by a single theory.

What do we mean by 'unifies' and 'accounts for' in this connection? I think we simply mean that by reasoning about the hypothetical entities (particles) with their hypothetical properties (such as elasticity and Newtonian behaviour), we can deduce the laws of their behaviour in various circumstances; and that the laws so deduced agree, within experimental error, with those derived from observations on actual gases. The empirical laws are 'unified' because they are all reproduced by deductions about a single model. A given law—say the relation $pv=c$—is 'accounted for' because it can be deduced from this model. This agreement between deductions from a set of hypothetical entities and relations, on the one hand, and the laws derived from observation on the other, seems to me to be the essence of scientific 'explanation'. The first qualification for a scientific theory is that we should be able to make deductions from it that agree with laws actually derived from observation. A theory is supported as a valid 'explanation' by all the empirical laws that agree with deductions from it. Conversely it is invalidated by any law at variance with such a deduction.

It does not matter, as far as the validity of the theory is concerned, whether or not the theoretical model leads to particularly simple mathematics. Provided that the deductions can be made, it does not matter whether the process is easy. We have not *a priori* reason to suppose that the laws of nature are all simple; rather we may suppose that we have only discovered the simplest of them.

MECHANICAL MODELS

It does not matter, again, whether the hypothetical entities and relations of the theoretical scheme are similar or analogous to systems that are already familiar. In the kinetic theory of gases, the particles have analogies with ordinary bodies, and behave according to the same mechanical laws. This was a favourite mode of interpretation in the nineteenth century; mechanical models were presumed to afford the best type of explanation. The

properties of light, for instance, were interpreted by the wave theory in terms of the mechanical laws of periodic motion which apply to, say, waves travelling along a stretched string. It was argued that we can understand a mechanical model, because in daily life we are familiar with bodies moving about or exerting forces; hence we understand light better if we show its analogies with mechanical motion. But the subsequent history of science, as well as reflection upon its method, suggests that the essence of scientific explanation is not to relate empirical laws to the laws governing some better-known system. For instance, the next stage in the theoretical explanation of the properties of light made it necessary to use two different and incompatible models in dealing with different properties—namely, the wave and corpuscle models. And at a later stage the two hypotheses were unified by the wave-mechanics, and it became quite impossible to visualise a model or to imagine any mechanical device corresponding to the mathematical theory. The variable ψ which occurs in the wave equations corresponds to nothing imaginable, and is significant only in so far as we can deduce, from the wave equation, expressions agreeing with empirical laws. By this criterion the wave equation is the best theoretical interpretation of the diverse properties of, say, hydrogen atoms, that has yet been put forward. A 'valid' theory, then, is primarily one from which expressions may be deduced that agree with empirical laws. A mechanical model is largely a concession to imagination, with functions something like those of a diagram in geometry; we find it hard to reason without imagining something at the same time. There is no harm in models, provided that their true function is recognised. They can be useful devices in reasoning and even in experimental work. But there is no reason whatever to think that they are *copies* of the fundamental realities of nature.[1]

THE CONSTRUCTION OF SCIENTIFIC THEORIES

The construction of theoretical interpretations is an affair of imagination and intuition, rather than of reason. By no process

[1] Cf. also below, 25, 42–4.

of strict logical deduction can we pass from empirical laws to the theories that unify them; the empirical laws do not imply a theory (though the theory implies the laws).[1] Theories are in origin constructions, not deductions; though once constructed they must be tested by the agreement of their consequences with observation. Everyone knows the story that Newton failed to see the connection between the motions of the heavenly bodies and the fact that bodies on the earth have weight, until he saw the apple falling. The sight stimulated his imagination and was the occasion of his intuition of a possible connection between the two sets of laws, which led to his formulating the general theory of gravitation. Intuition and imagination constructed the theory. But until it was successfully tested against observation, it was not established as a scientific explanation. Whether or not the story is an invention, the moral is sound: scientific life calls into play other faculties besides reason, but the credentials of scientific beliefs are purely rational.

Contrary to a common belief, successful prediction is not of any special value in supporting a theory. Whether deductions from the theory precede or follow the experiments makes no difference to the degree of support they lend to a theory. It does, however, make the difference between a theory that remains a museum piece and one that helps the extension of scientific knowledge. By drawing out the logical consequences of a theory, and seeking experimental results that agree or disagree with them, one obtains wider evidence about the theory, and this is in fact the way in which theories are commonly refined and improved.

AN OBJECTION

It might be objected that what I have described is not the method common in current physical science, in which theory and experiment are fairly well integrated and experiments are commonly performed in order to test some hypothesis. This is perfectly true; I have been trying to present the method of obtaining scientific beliefs in such a way as to show their logical genesis

[1] I use 'implies' in the sense of 'strictly implies' throughout, i.e. as the converse of 'deducible from'. Thus '*p* implies *q*' means the same as '*q* is deducible from *p*'.

(which is to some extent also the order of their historical evolution) —the dependence of laws on observation, the supporting of theories by deduction of laws from them. My account of physical method should therefore be checked not so much against the accounts of experimental work in, say, a current journal of physics, but rather against the historical development of beliefs about nature, and better still against the presuppositions of any particular experiment in modern physics. My account is more concerned with the relation of the most elementary facts to physics as we know it, than with the technique of modern physical investigation.

MATHEMATICAL CHARACTER OF THEORETICAL INTERPRETATIONS

The kind of understanding of nature that we can expect from physical science is dependent on the character of the theoretical scheme. It is of the first importance that the hypothetical entities and relations of this scheme are, and must be, defined mathematically. For instance, the mechanical properties of bodies are summed up in the mathematical statements called Hamilton's equations; the wave properties of light are epitomised in Maxwell's equations; the properties of the hydrogen atom are expressed by its wave-equation; the 'particles' of the kinetic theory of gases are characterised mathematically. From such an equation the law corresponding to the behaviour of the system in given circumstances can be deduced by ordinary mathematical reasoning. This law is compared with the empirical law actually derived from observation. If the agreement is satisfactory, the theoretical hypothesis is so far a satisfactory one. Reversing this argument, we see that the theoretical scheme *must* consist fundamentally of mathematical equations. For, empirical laws in physics consist of functional relations between variables expressed as equations—for example, $pv = c$—and our theoretical scheme has to reproduce these. But an equation can only be deduced from other equations. So the theoretical scheme, from which a variety of empirical laws can be deduced, must itself consist of equations.

What, then, are we to say of mechanical models? Evidently it is not the analogy with everyday bodies that is fundamental in mechanical explanations. The important thing is that the laws of behaviour of a mechanical model can be mathematically expressed. The solidity and familiarity of the model are valuable only in so far as they satisfy and stimulate our imagination; as we say, they 'fix our ideas'. It is the mathematical equations that they embody that are fundamental in their use as physical explanations. These equations are formally analogous to the equations which 'save the phenomena'. For instance, the equations that describe wave motion along a string have certain analogies with those that express part of our knowledge of the behaviour of light. But this is merely an analogy of mathematical form, and is no argument for a fundamental similarity between an oscillating string and a beam of light. The initial value of the analogy was heuristic; the laws of wave motion of strings were already known when some optical phenomena were discovered which proved capable of unification by analogous equations. Similarly the equations that unify our knowledge of the behaviour of gases have certain formal analogies to those for a system of perfectly smooth elastic balls moving rapidly about in a large enclosure. But these analogies do not themselves show that the gas consists of smooth elastic spheres; only that it behaves in some respects as if it did. The value of the mechanical analogy as explanation is nil except in so far as it gives the correct equations. Its great value is as a tool, a sort of lever for the imagination, in the process of investigation. It is of use in discovering, not in supporting, the correct mathematical theory. It may make the theory more interesting, but it does not constitute evidence.[1]

Thus the fundamental requirements for a physical theory are that (i) it must be expressible quantitatively, as a mathematical equation or a set of equations; and (ii) from these equations it must be possible to deduce expressions for comparison with the equations expressing empirical laws. If a theory embodies a model that can be visualised, this model is only of interest, from

[1] Cf. below, pp. 42–4.

the point of view of the validity of the theory, in so far as it represents equations from which deductions can be made; though it may well be valuable in so far as it aids memory and imagination in scientific investigation.

SCIENCE AS EXPLANATION

In what sense, then, does science give us an understanding of nature? From the foregoing a preliminary answer can be given. In the first place, science 'explains' phenomena in the sense that it shows us interrelations between them, by showing how the laws of very diverse phenomena can be deduced from relatively few principles. From the few mathematical expressions of the kinetic theory of gases, for instance, we can deduce expressions for a varied collection of phenomena involving gases. And, secondly, we understand nature better if we can give concrete form to our common-sense belief that its phenomena are not a mere planless flux, but are related by necessary connections. We shall return to this later.

THE DIALECTIC OF THE GROWTH OF SCIENCE

Physical science develops continually, and its development exhibits a certain dialectic. This development is no doubt partly dependent upon external factors such as finance and facilities; but we are here concerned with the inner dialectic of scientific life itself.

The inner laws of the growth of science depend upon its method. Science grows both in scope and in unity. It investigates new fields, new phenomena: the great developments in mechanics, for instance, came only after 1500, in electricity after 1700, in heat after 1800, in electronics after 1900. Thus the scope of science, the variety of its interests, is enlarged. Moreover, the fields may begin to link up; thus the study of heat began in the nineteenth century to overlap with that of light. These new phenomena demand new theories. Further, the aim of theory is not only to unify the phenomena of each field, but to link up those of diverse

fields. Thus electromagnetic theory links up electricity, magnetism and the radiation of heat and light; relativity theory links up electromagnetic theory and mechanics; Eddington's later work was concerned with the unification of relativity and quantum theory. The advance in theory is thus both extensive and intensive: the new hypotheses cover new ground and they effect a more complete logical unification.

Experiment and theory, moreover, are interwoven. Not only are theories framed to unify the new observations, but the new theories suggest new experiments which may support them. An effective theory is one that is not only self-consistent, well supported and of manageable complexity, but is also fruitful in the sense that it suggests feasible experiments. If the results agree with the deductions from the theory, they support it; if not, the theory must be improved until the discrepancies are eliminated.

Because of this continual development of science, no theory can be regarded as permanent. This is why theoretical interpretations are often called hypotheses. It is taken for granted that one day they will be superseded. Few theories have become so venerable as to outlive the ephemeral and fugitive air of the general run of hypotheses. New observations strain the bonds of the old theory and eventually a new theory, adequate to the new observations, must be found. Yet a discarded theory usually lives on to some extent in its successor. The development of theory is not well described as simply an advance from incorrect to correct. The old theory may appear as a special case of the new—thus, classical mechanics is a limiting case of quantum mechanics; or it may be a crude adumbration of a notion which is given precise form in the later theory—this is true of the old and new stereochemistry, for example. The advance is from a view less widely applicable to one more widely applicable; or from a relatively vague to a relatively precise account; or from a less accurate view to a more accurate one. Incidentally, this impermanence of scientific beliefs, so well established as an historical fact, should give pause to those who seek to base philosophy upon the conclusions of science at any particular time.

PRELIMINARY CONCLUSIONS

Beginning with an examination of its method, we have now reached preliminary conclusions about the subject-matter, the point of view, and the kind of knowledge gained by physics. The subject-matter is inanimate matter; the point of view is that of measurement and correlation of the quantitative aspects of matter. The method consists of observation, correlation of variables, and construction of empirical laws; followed by the construction of a theoretical scheme such that equations deduced from it agree (within experimental error) with the empirical laws, and experimental verification of any consequences of the theory that have not previously been examined. The theoretical interpretations are impermanent; but they effect a logical unity between phenomena, in that the laws of many different phenomena can be reproduced from relatively few theoretical principles, and to this extent they 'explain' the phenomena. They do not give us a complete knowledge of the nature of matter, but they are evidently significant of it, in some way we have not yet determined.

CHAPTER III

The Scope of Physics

WE have now to inquire, what is the scope of physics? To which of the problems that vex the human race can we apply it, and what sort of knowledge can we expect from it? These are topics about which many answers are proffered, and many mistakes committed. One reason for these mistakes is that commonly only the conclusions of physics are considered, and not its method and presuppositions. This is an unsafe method, as is evident from the fact that leading conclusions of physics have changed several times within fifty years; so that in matters of importance it is unsatisfactory to rely upon their implications, even assuming that these have been correctly inferred. For a constructive view we must look further. To define the scope of physics, therefore, we are examining its method. For the method of physics reflects its subject-matter and point of view, by which it is determined, and in turn it determines the kind of knowledge that physics can provide. By considering its method we can therefore come to an estimate of the field to which physics is applicable, the limits of its outlook; and so derive a view of the place of physical knowledge in our general world-view. We shall take up, therefore, the statements of the last chapter, that the method of physics shows that its subject-matter is inanimate matter and its point of view that of measurement and correlation of variables; and consider in turn the limitations thereby imposed on the scope of physics. Finally we shall consider some limitations that have been revealed by the progress of physics itself.

THE SUBJECT-MATTER OF PHYSICS IS INANIMATE MATTER

Physics and living organisms. As we noted in the last chapter, living organisms are peculiar among material systems, in that while, as physiology shows, processes in them can be described in

terms of physical and chemical laws, the sequence of arrangement of these processes is 'organised', 'co-operatively harmonised',[1] in a way that is not exhibited by the inanimate systems studied by physics. Besides the order described by ordinary physical law, there is in organisms an order which directs the physico-chemical changes in relation to the master-functions of the organism—maintenance, development and reproduction. These chief functions, moreover, are organised in a definite life-cycle, a dynamic pattern in time; they are subserved by the control of internal conditions such as temperature and blood composition; by metabolic interaction with the surroundings, a succession of inorganic molecules forming temporary parts of the structure without their replacement affecting its peculiar organisation; and by activities that are 'directive' or 'goal-directed', such as the healing of wounds.[2] The normal state of the organism, which these directive activities subserve, is distinguishable from the stable equilibrium which is the result of automatic processes in inorganic nature, in that it is maintained only by constant activity of an elaborate and co-ordinated kind, unparalleled in physics. A striking illustration of the distinction that these facts suggest between organisms, with their special unity and co-operation of parts, on the one hand, and matter controlled only by physico-chemical laws, on the other, is provided by the following observations on one of the fresh-water worms called Planarians.[3] By destroying certain neural centres of *Planaria albissima*, the worm can be made to shed the proboscis by means of which it eats. The proboscis then moves about in the water swallowing every small object it meets; it shows no discrimination, and takes in particles of glass as readily as food. It will even turn upon the body of which it had recently formed an organised part, and eat its way through from one side to the other. This behaviour is in strong contrast to the behaviour of the organ while it is under the normal control of the organism as a whole; it then displays a nice discrimination in accepting particles of food and rejecting other particles, and serves the ends of the

[1] Sherrington, *Man on His Nature*, pp. 78, 79.
[2] Cf. E. S. Russell, *The Directiveness of Organic Activities.*
[3] Cf. E. S. Russell, *The Behaviour of Animals*, p. 12.

animal as a whole. Separated from the organism, it is at the mercy of external stimuli; united, it is co-ordinated with the self-caused behaviour or 'immanent' activity of the organism.

Such are the facts; how are they to be interpreted? It does not seem possible to maintain that organisms differ only in complexity from inanimate systems. The order and unity exhibited by organisms seems to be different in kind from that of inanimate matter; we cannot describe it without introducing concepts such as directiveness, which are not needed in physical science, but which continually obtrude into descriptions of organic behaviour despite attempts to do without them. There are certainly *analogies* between the behaviour of organisms and of physico-chemical systems; thus in thermodynamics we speak of 'spontaneous' changes, and the second law of thermodynamics is a statement of a general direction of physico-chemical change. But the word 'spontaneous' here does not seem to mean exactly what it means when applied to an organism; the spontaneity seems to be different in kind. It is the same with terms like 'directiveness', 'unity', 'order', 'equilibrium'—they are ambiguous terms; their meanings when applied to organisms and inanimate systems are perhaps analogous, but are not identical. (Professor Schrödinger, in his brilliant book *What is Life?* seems to mistake these analogies for identities when he likens the order of an organism to that of a clock, or a crystal at the absolute zero of temperature.) Physical laws cannot completely describe the order that rules an organism; besides the detailed explanations of events in the organism afforded by the physico-chemical approach in physiology, we need to account for the order, the pattern in space and time, of those events; and this requires the explanatory concepts peculiar to the study of organisms. Nor is there any reason why concepts such as directiveness should be regarded as mysterious or occult simply because they lie outside the range of physics; there may well be concepts in biology which are not reducible to those of physics (though perhaps analogous to them); just as moral philosophy uses many concepts, such as that of duty, which are not reducible to those of biology. Physical experiment will not reveal the

characteristics peculiar to living organisms, because the method of physics omits them from consideration; we shall not find anything in an organism contrary to physical laws, but if we examine the organism as such, and the characteristics peculiar to it, we shall find its own organic unity and order superimposed on the physical laws.

The view that seems best to fit the evidence is, then, that in organisms the physico-chemical units of matter—atoms, molecules and so on—are in a different kind of situation from that in inanimate matter; superimposed on the order of inanimate nature is another kind of order characteristic of organisms, manifested in the tendencies to preserve life, to develop and to reproduce, in metabolic interaction with the environment, in the subordination of parts to whole, and in 'directive' activities. This view is neither mechanist nor vitalist; it might be characterised as the 'organic' position. Whitehead called it 'organic mechanism',[1] but its pedigree is from Aristotle. As against vitalism, it does not require any 'life-force' in organisms; as against mechanism, it recognises that organisms have characteristics that are not reducible to physics. It accepts the triumphs of the applications of physical method to organisms, as in physiology; noting, however, that they deal with selected aspects of the behaviour of the organism, with the properties that it has in common with inanimate matter, and omit its specific characteristics.

Physics and the 'freedom of the will'. The same kind of problems arise when we consider beings which are both material and intelligent, namely human beings. The human body is a material system; material systems are subject to the laws of physics; are we therefore physically determined in our thoughts and behaviour? Here, however, the matter is less difficult, because when we are considering human beings we have direct access to important evidence that is hidden from us when we consider lower organisms, namely the data of our own consciousness and of social intercourse. The burden of the evidence is that man is capable of rational thought and action; he commonly argues logically from factual evidence to conclusions, and directs his

[1] *Science and the Modern World*, Chapter V.

actions according to principles. Science itself in practice provides excellent instances of rational thought and action; in the course of any piece of research one may observe rational practice in drawing inferences from evidence, learning from experience, in adaptation of means to ends, in action based on reflection, in recognition of duties and so on; here in miniature are all the characteristics of rational life, and anyone who lacks evidence of the control of human behaviour by reason would do well to take part in scientific life. Moreover, it is impossible to produce any argument against the rationality of man without self-contradiction; if a man tells me that all men are controlled by physical laws and not by reason, he must hold that his own opinions are similarly determined and do not result from rational interpretation of evidence, so that I am under no obligation to believe him. In practice, argument and purposive action are very general among mankind, and we may take it that no one consistently holds that he is not rational. The behaviour of my body, then, is subject not only to physico-chemical laws and to biological co-ordination, but also to occasional directives by reason, when I carry out some action that I have decided upon with some end in view.

But how is this to be reconciled with the fact that physics knows nothing of purposes and reasoned decisions? The answer is very simple: physics knows nothing of these matters not because they are imaginary, but because it pays no attention to them; it carefully excludes, from the outset, all mention of human acts; it ignores all the characteristics peculiar to the intelligent actions of human beings. The physical account of an experiment, for instance, records only the values of the physical magnitudes concerned; it does not mention that the experiment was conducted by a human being who (if he was in his right mind) was acting rationally, after deliberation and with some objective. Reflection on the characteristics of rational behaviour is irrelevant to the conclusions of physics; and, correspondingly, the conclusions of physics are irrelevant to the discussion of rational behaviour. Since all consideration of human acts has been excluded from physics at the start, clearly there will be nothing about them in

its conclusions. Physics confines itself to the examination of inanimate matter; our conviction that rational action is possible, and that we are not the slaves of physical law, is derived from data that are inaccessible by the method of physics, and do not therefore appear in its conclusions. This omission does not imply that we are not rational, but that the scope of physics is limited. The conclusions of physics have thus no bearing whatever upon rational action, or, in the more familiar phrase, the 'freedom of the will'.

It is of interest to inquire into the reasons for the attractiveness of the mechanist view that the behaviour of organisms, and of men in particular, is not merely compatible with physical laws but can be wholly accounted for by them. Historically it derives largely from the sharp dichotomy of Descartes between 'mind' and 'matter'; the essential activity of mind on this view being to think, and the essence of matter to be spatially extended. If such a distinction be accepted, it is difficult to see how 'mind' and 'matter' can interact, and indeed Descartes' system issues in a view of man as 'a ghost in a corpse'; moreover, animals lacking the power of conscious thought must be mere machines. Since these conclusions do not square with the evidence, the original distinction must be re-examined, and the solution is evident: thinking and extension do not manifest the presence in man of two different beings, but two elements of one being, which is both extended and capable of thought. 'Body' and 'mind' are parts of one whole, the human organism, and difficulties only arise if they are conceived as separate entities. Even when this is recognised, however, there remains a certain plausibility about the argument that, because men and other organisms are material, their behaviour must be determined by physical laws alone. This, I think, is because the argument appeals to an analogy, which is, however, a misleading one. The argument is of the following type: *A*, star, is material and is subject solely to the laws of physics; *B*, a man, is material; therefore, by analogy, *B* is subject only to the laws of physics. The argument is fallacious because the analogy is not close

enough and breaks down at the vital point; the star and the man differ in precisely the point at issue. To suppose the analogy valid is to beg the question. The full range of the evidence about man can only be interpreted if we allow that he is capable of rational thought and action.

Some would attempt to reinforce this conclusion by pointing out that the great argument of nineteenth-century mechanism has gone; namely the claim that, given complete information about the state of the universe as a physical system at one moment, its state at a later moment could in principle be calculated and is uniquely determined. Since the discovery of quantum phenomena and Heisenberg's uncertainty principle, this claim is no longer tenable; the present state of the physical system is theoretically compatible with a variety of future states; and it might be argued that this gives some rope to the organism, some freedom of choice to the man. Eminent scientists have conceived this to be a way of escape from universal physical determinism.[1] But there is in fact no need to appeal to the uncertainty principle. For even if the present state of a purely physical system determines uniquely its future states, the same is not true of a world that includes rational beings and organisms as well as systems subject solely to physical laws; where rational action or organic control are possible, superimposed on physical law, one must modify statements based on the behaviour of inanimate systems alone. The root error is to presuppose that human beings and organisms are nothing but complex inanimate systems, or that in admitting their special characteristics one is denying that they are subject to physical laws. No doubt the indeterminism of modern physics makes easier the reconciliation of physics with common sense; for it implies that the particular state of my brain now is physically compatible with any one of many different states an hour hence, so that there is no difficulty in harmonising self-determination with physical law. But whatever the difficulties of harmonisation, it should always have been evident that the findings of physics are

[1] Cf. Eddington, *Nature of the Physical World*, Chapter XIV; Jeans, *Physics and Philosophy*, Chapter VII; Planck, *Where is Science Going?*; Whittaker, *Proc. Physical Society*, vol. lv, p. 459 (1943).

irrelevant to the discussion of human freedom, because the analogy between inanimate matter and man is here inadequate.

Physics, then, ignores all the characteristics peculiar to intelligent beings; it is not by the method of physical science that we can discover the nature of man. We cannot expect from physics an account of beauty, of reasoning, of friendship, or of immortality. Physics does not discuss the place of science in the good life, nor the aesthetic value of science and its particular version of intellectual beauty; it does not examine its own fundamental presuppositions, nor the grounds for believing them to be true. For answers to such questions we have to turn to philosophy.

THE POINT OF VIEW OF PHYSICS IS THAT OF MEASUREMENT AND CORRELATION OF VARIABLES

Qualities disappear in physical descriptions of nature. Throughout physical science an elementary part of the procedure is to represent differences of quality by differences of some corresponding quantity by a series of different numbers. For instance, material bodies have inertia, that is, they resist changes in their motion; in physics the qualitative notion of inertia is replaced by the quantitative conception of mass, which can be related to measurable quantities. To a labouring man, there is a vast qualitative difference between an iron sledge-hammer and a wooden mallet of the same shape and size; they are used for quite different jobs, there is a world of difference in the handling of them. But to the science of particle dynamics the only relevant difference is in the numbers representing their masses. Again, colours are infinitely various, qualitatively distinct; but in physics we omit the qualitative aspects and represent the colour by the wavelength of the light. Further, in a patch of colour we can distinguish three qualities: the hue, the brightness or dullness, and the depth or paleness. In scientific colorimetry these are replaced by measurable quantities. By measuring the coloured patch against a mixture of a pure colour (the blue of the sun's spectrum, say) with white light, one can specify it in terms of the wavelength of the pure colour, the relative intensities of white light and pure colour when a match

is obtained, and the total intensity needed for a match. Thus the deep rich colours of a Titian, the pure luminous effects of a Botticelli, the evening splendour of a Canaletto, the pale clarity of a summer dawn—all are represented for optical purposes by sets of numbers. The qualities and their harmonies are omitted from consideration, and of course the unity of a painting is ignored. It is the same with music: the measurable properties of any sound can be specified in terms of pitch, loudness and overtones, and the difference between the thin tone of a shepherd's pipe and the full diapason of an organ are represented in scientific acoustics by a set of numbers. Melody, harmony and counterpoint are naturally excluded from consideration by this procedure. And so on; examples could be multiplied.

It would evidently be absurd to suppose that we have in any way altered the sledge-hammer, the picture or the music by thus describing them in terms of numbers. We have not analysed them into something else, nor 'debunked' them, nor even simplified them. They remain what they were, with their irreducible qualitative differences, their artistic unities, and their power to move men's minds. We have simply omitted a great deal from consideration, taking into account only the quantitative aspects of things. Humanists have been horrified at the failure of science to express humane interests—'What a world is this that science shows us —cold, dark, and shaking like a jelly!' But the fault is not with science, whose method confines it to the measurable, so that it cannot show us the world as a whole, but only its quantitative aspects. In place of the world of men, of living things, and of art and literature, physical science gives us a diagrammatic sketch, from which not only life but the forms and colour of everyday life are omitted. Yet the sketch has its own beauty and its own value, as we shall see, for it reveals that there are unsuspected harmonies in the quantitative aspects of phenomena.

The omission of colours, scents and sounds from the physical account of matter does not, then, imply that these qualities are non-existent or unrelated to matter. Again, the fact that the account is mathematical does not mean that matter consists of

mathematics. That the mathematical description can be thought does not imply that the thing described (nature) consists of thoughts. We have to be careful to distinguish between a description and the object of the description. Matter is not dematerialised by describing it mathematically; it is not reduced to 'waves of probability' nor any other model or set of equations. Those are only descriptions of it from one point of view, valid within its limits, but incomplete.

Agents and causation omitted in the physical description of nature. In ordinary life we generally think, not so much in terms of events succeeding one another according to a rule, as in terms of people and things acting as causes. In human affairs we are concerned with Mr. So-and-so acting as a cause of some change, such as his mending a bicycle or planting a fruit tree. We think in terms of a person, an agent, acting as a cause and producing changes in himself or other people or in things. And by causality we do not simply mean that events succeed one another according to a rule; we mean that there is a necessary connection. If I say 'Achilles killed Hector', I obviously do not mean that every time Achilles fought with Hector, Hector subsequently died. I mean that there was a necessary connection between two unique events, Achilles' blow and Hector's death; also, that Achilles was the agent that caused, or partly caused, those effects. I do not necessarily mean that Achilles intended Hector's death; a cause need not intend its effects, nor need it be aware of them; Achilles might have been drunk, and it is meaningful to say 'I have been the unwitting cause of that man's misfortunes'. Concerning events in nature, too, we think in terms of necessary causal connections. If I say 'the flood caused a landslip', I do not mean simply that every time such a flood occurs such a landslip also occurs; I mean that there was a necessary connection between two (possibly unique) events. Causality, then, does not in normal language mean just regularity; it denotes a necessary connection.

This necessity is not merely logical. The flood did not logically imply the landslip, as the proposition '*x* is red' implies '*x* is coloured'. Logical implication is one kind of necessary relation,

which holds between propositions. Causality is another kind of necessary relation, which holds between facts, or between agents and the changes they effect. If x always equals $2y$, and y equals 2, then x equals 4; that is implication, an affair of propositions. If a real flood occurs, and as a result a real landslip follows, that is causality, an affair of facts. There is a great difference in our insight into the two sorts of relation. We can recognise implications simply by virtue of our insight into logical relations and fallacies, summarised in formal logic. But causal relations, when we come upon them in experience, may be quite opaque to our understanding. It may be quite obscure to us why (say) a dose of vitamin C should accelerate the growth of rats, while a dose of arsenic kills them; our attention is only drawn to the causal relation by the discovery of empirical laws about rats and their food.

Now in physical science, as we have seen, the typical statement is not '*A* causes *B*', as in most human affairs, but '$pv=c$', or more generally 'x equals $f(y)$', that is, 'x is a function of y'. We deal with laws, instead of with causes. From physical experiment we can only derive such functional relations. They are logical relations; the equation $pv=c$ asserts a logical relation between the value of p and the value of v, since the numerical value of v is deducible from that of p; it asserts a relation of implication between two propositions involving numbers. But changes in pressure and changes in volume are not numbers, but events; if there is a necessary connection between them it must be causal, not logical—concerned with facts, not with propositions. For this causal relation our physical scheme has substituted a logical relation. This does not cast doubt upon the causal relation, which cannot be reduced to a logical one; it is simply a descriptive device. Evidently the logical relation, such as the equation $pv=c$, corresponds to some causal relation. We may perhaps say that it 'symbolises' or 'is significant of' some causal relation holding in nature. The regularity of behaviour described by the law manifests the causal relation to which it is due. Thus, although we have no insight into the causal relations of inorganic matter,

we can symbolise them by the functional relations that constitute empirical laws; these laws are significant of the causal relations in nature. Causality is symbolised by deducibility. The logical order of the theoretical scheme, too, appears to be significant of order among the causal relations in nature; it manifests the order in nature.

Causality, then, is expelled from the physical scheme in favour of lawfulness, expressed by mathematical relations. The cleavage between the language of physics and that of common sense could hardly be more complete. The conclusion from this is not, however, that common sense is inaccurate, or inadequate to its purposes. People and their actions are by far the most important objects of our attention, and to understand and describe them we must use the general notions of agent and causality. The affairs of greatest moment to us are concerned with intelligent agents and the effects of their actions; we even, in metaphor, carry over the mode of speech appropriate to human actions to events in material nature. Moral philosophy and metaphysics must use the notions of agent and causality explicitly in commenting on the good life and the nature of man. That physical science does not mention these notions (at least explicitly) simply reflects its limited scope and special viewpoint, which lead to a method that ignores them. Those who call on us to stop thinking in such terms are surely forgetful of the needs of everyday life as well as of metaphysics and ethics. Physical method is not the norm for all rational studies; it is only one version of the method of reason interpreting experience, adapted to a very restricted field. Causal processes continue to occur, whether physics mentions them or not.

Status of the explanatory theoretical scheme of physics. We must now inquire into the status of the explanatory scheme by which we interpret the laws derived from experiment, and see whether it gives us any understanding of nature.

If we consider some part of the theoretical scheme of physics —say the kinetic theory of gases, the wave theory of light, or the wave-mechanical equation for the hydrogen atom—we find that it consists essentially of a system of equations. (The wave-equation

is a 'pure' example of this; most other examples embody 'models' which, as we saw in Chapter II, are supported only in so far as they embody certain systems of equations.) What is their relation to the data of experience? Evidently they are constructions of the mind, but with this foundation in reality, that deductions from them agree with the empirical laws derived from experience.[1] They 'explain' phenomena in the sense of providing a logical unity among empirical laws. They are not deductions from these laws, any more than the laws are deductions from the observations; they are not strictly implied by the evidence adduced for them.[2] Indeed it is hard to say exactly how that evidence positively supports them, and to what degree.[3] They are attempts to interpret the evidence, to grasp reality through the data, in so far as the self-imposed limitations of physical method allow. They are, however, not necessarily the only interpretations that would be consistent with the evidence, nor, necessarily, the neatest mathematically. In practice they are ephemeral, subject to alteration and development. They must, however, depend in some way and to some extent upon the nature of matter, and so must be in some way 'significant of' that nature. Unfortunately the mathematical expressions contain symbols that do not stand for anything that can be imagined, and have meaning only in as much as they can be related to observable quantities. Thus the ψ of the wave-equation for the hydrogen atom by itself represents nothing imaginable, but it can be related to the spacing of the lines in the

[1] The phrase 'construction of the mind with a foundation in reality' is an attempt to translate the useful phrase *ens rationis cum fundamento in re*. Cf. Maritain, *The Degrees of Knowledge*, Chapter III; where, however, it is mistranslated in the English version as 'rational being', to the great confusion of the reader.

[2] In general terms, if a proposition p implies another, q, and q is true, we cannot deduce from this that p is true. For instance, 'This is red' implies 'This is coloured'; now, my table is coloured; but I cannot conclude that it is red. Similarly, the kinetic theory of gases implies that the equation of state of a gas at constant temperature is $pv=c$; and in fact the observations lead to this law; but we cannot deduce from this evidence alone that the theory is true (though it may be). But this does not forbid us to think, when a theory predicts a great many empirical laws that are all verified, that we have rational grounds for believing it to be likely. Cf. Chapter IV.

[3] The empirical evidence supports them negatively, in the sense that it rules out those alternative theories which lead to conclusions at variance with experiment. But how the evidence positively supports a theory is much harder to say; the theory of induction has so far shed little light upon the fundamentals of scientific theorising. Cf. Chapter IV.

spectrum of hydrogen. It is somewhat like the square root of minus one; we never meet an instance of that number, and we cannot imagine one, yet the symbol $\sqrt{-1}$ has meaning because by a suitable mathematical operation it can be related to ordinary unsophisticated numbers. The theoretical scheme of physics gives us no full insight into the intrinsic characteristics of matter; we can draw from it no clear conclusions about the essential nature, the fundamental character, of material objects. Not only are causes and effects replaced by functional relations, but the symbols occurring in these relations are not transparent to us; though they must in some sense be signs of something that corresponds to them in reality. We cannot therefore gain from physical theory anything more than an image of the nature of matter. We see as in a glass, darkly. The theoretical scheme must in some way symbolise, but does not give us any ultimate knowledge of, the nature of matter.

Status of models in the theoretical scheme. Models are not to be despised, since they help our imaginations and are therefore indispensable both in teaching and research; but equally they are not to be mistaken for descriptions of the essential characteristics of nature. As we saw in Chapter II, they are fundamentally analogies. They are not sheer fictions on the one hand, nor adequate descriptions on the other, but analogies. For instance, the equations that unify the laws of the behaviour of light in certain experiments (Maxwell's equations) are similar in form to those representing the wave motion of a stretched string. The correct way to regard the analogy is as a help to memory and imagination, not as an explanation nor as revealing the nature of light. The approach that we can now see to be incorrect is that of the nineteenth-century physicists who presumed that analogous equations must correspond to similar realities, and concluded that light *is* a mechanical wave-motion, an oscillation of a material 'ether'. Later experimental work made it clear that if there were any such medium it had not the ordinary mechanical properties of matter. At the time, this result was found highly astonishing. Reflection on the methods by which the model

was derived could have shown that it was no more than an analogy, and so, like all analogies, was likely to break down if pressed too far. Since the analogy adds nothing fundamental to the explanation provided by Maxwell's equations, its breakdown did not imply that the theoretical equations were incorrect, but only that its application had been stretched too far.

Again, as time went on, empirical laws about the behaviour of light in certain circumstances were discovered that could not be deduced from Maxwell's equations. The wave picture (more accurately, the wave analogy) did not apply to them. Another analogy, that of particles, was found useful. Thus the behaviour of light required two analogies, the wave and the particle, according to the circumstances—according to the system with which the light was made to interact; a position which called forth the celebrated remark of Sir William Bragg that one view had to be used on Mondays, Wednesdays and Fridays, and another on Tuesdays, Thursdays and Saturdays. At the time, this caused considerable perplexity. The situation was certainly unsatisfactory to science, because the unification of empirical laws by theory was incomplete until a mathematical scheme was evolved in which the wave and particle theories were included as special cases. But it appeared that in some quarters the perplexity was about the question 'How can science lead to two incompatible views about the nature of light?' This question is a spurious one, and the perplexity was misplaced. The wave and particle models are not views about the nature of light, but analogies for its behaviour. Different analogies were needed for different phenomena—somewhat as we might say of someone that he is like an angel at home and like a devil at his office. We do not mean that the man has two natures; only that we cannot find one analogy that will do justice to his behaviour in all circumstances. If we could find a single analogy that would do so—if we called him a Jekyll-and-Hyde, for instance, or likened him to one suffering from schizophrenia—we should be more satisfied that we understood something of the man's character. So with the wave and particle theories: if we can unify them, so much the better for

science; but if we cannot, we are not confronted with an apparent clash of truths, but with a mere failure of analogies. All analogies break down if pressed too far; if they did not they would be identities, not analogies.

Finally, it will be clear by now that when interpreters of science are perplexed because the wave-mechanical account of (say) the hydrogen atom appears to reduce it (as they say) to a 'wave of probability oscillating in nothing in particular', the reason is that they are looking for a mechanical model where none is possible. The wave-equation is a mathematical statement that 'saves the phenomena', and that is all that we can ultimately ask of any theory in physics.

SPECIAL LIMITATIONS OF PHYSICAL OBSERVATION AND THEIR CONSEQUENCES

The finite and constant velocity of light. Experiment indicates that there is an interval of time between the occurrence of an event and our seeing it; it leads us to believe that light travels with a finite and constant velocity, independent of the motion of the observer. This impossibility of detecting an event at the same instant that it occurs is a further limitation on physical observation, discovered by physics itself, additional to the limitations imposed by the method of physics.

Moreover, supposing the event to be a flash of light from some source, it will give rise to different observations by two observers of whom one is stationary relative to the source while the other is travelling rapidly away from it. If a series of light flashes occurs, they will appear to the moving observer to happen at longer intervals than those recorded by the stationary observer; the two observers will have different time-scales. The apparent distances between two sources emitting such sets of light flashes will also depend on the relative velocities of the observers and the flashes; the two observers will have different scales of distance. But, using the empirical law that the velocity of light is constant and independent of the motion of the observer, it is possible to relate these time and distance scales to each other, and to find, in place

of the apparent time intervals and distances, which are no longer independent of the observer, some quantity that does not vary from one observer to another. This turns out to be the quantity called the 'space-time interval' of the theory of relativity; in place of a distance determined by three spatial co-ordinates (x, y, z), and a time interval determined by a temporal coordinate (t), we have to use a quantity that is a function of all four, namely $(x^2+y^2+z^2-c^2t^2)$. To obtain a frame of reference common to all observers, then, we have to use a quantity that is a function of both spatial and temporal intervals.

These are in briefest outline some of the essential facts about the special theory of relativity. Evidently it is a mathematical device, designed to deal with the conclusion from experiment that even the fastest indication of an event takes a finite time to reach us. It had the great merit of redirecting attention to observable phenomena and away from arguments about models such as the 'luminiferous ether'. Yet in its wider presentation the precise mistake that has often been made is the attempt to find something to visualise. Ingenuity has been wasted on something alien to the theory—on attempts to make a model of a space-time continuum, which is only a name for the mathematical calculus in which x, y, z and t occur. This has obscured one of the lessons of the theory, namely that physics must attend primarily to observables and their mathematical unification, and should not regard models as anything more than analogies.

Not only is it impossible to visualise a four-dimensional space; it is a mistake to regard it as anything more than a mathematical device. Because time intervals occur in the same formula as distances, we cannot conclude that they are in any way similar, still less that time has been reduced to length, or vice versa. I am aware of extended objects and of events following one another; the extension and the before-and-after are different in kind (though each has a measurable aspect), and neither can be reduced to the other. We cannot conclude from the relativity theory that length and time, which in experience are so completely different, differ only in appearance. The theory of relativity gives no support to this

notion; it is simply a consequence of the limitation on observation due to the finite and variable time-lag in our fastest signalling systems.

The 'uncertainty principle' and causality. When we want to determine the thickness of a coin, we can do it with a pair of calipers or a screw-gauge; the pressure of the metal jaws of the gauge produces so little deformation of the coin that it can be neglected. If we tried to measure the thickness of a wad of felt in this way, the gauge would compress the felt as we screwed it up, and the thickness measured would depend on the pressure applied; the measurement would be affected by the interaction of the felt with the measuring instrument. In somewhat the same way, when we try to measure the position of an atom, or especially of an electron, the most delicate probe we can use (radiation) is violent enough to disturb the system and give it an appreciable velocity. It emerges that the more accurately we observe position, the less accurately we observe velocity, and vice versa. This is Heisenberg's 'uncertainty principle'. It is evidently concerned with the impossibility of accurate observation of events on the atomic scale. It expresses a limitation on physical observation. Lawfulness is not observable in systems of atomic scale, at least not in the usual physical sense. Exact mathematical laws cannot be formulated for such systems; only for aggregates of large numbers of them, which follow 'statistical' laws.

This is an important conclusion for physics; but it may be questioned whether it has any wider significance. That laws cannot be derived from the behaviour of a single system of atomic scale does not imply that the system follows no laws; it simply reflects the fact that our methods, limited as they are by the crudeness of our probing devices, cannot, even in principle, discover them. Still less does it prove anything about causality. Causality in nature implies necessary connections between events. Such causal relations would be expected to give rise to laws, such as are in fact derived from experiment for many phenomena. But if for a given phenomenon we find that we cannot formulate a law, because of inadequacies in our means of observation, we

ought not to conclude that there are no causal relations determining the behaviour of the system. 'Unpredictable' does not mean 'uncaused'. When we say that a man's actions are unpredictable we do not mean that he is not master of them, but only that we cannot get inside his mind and understand his motives. It is the same with nature; the fact that we cannot find regularities simply reflects the quantum limitation on observation, and has no bearing on causality, one way or the other. Statements to the effect that the uncertainty principle implies a 'breakdown of causality' are therefore extravagant and quite without basis.

The empirical law connecting the rate of decay of radioactivity with time has been interpreted by a hypothesis that would entail that the instant of disintegration of a given radioactive atom is not predictable, even in principle. Various ways in which this apparent lack of lawfulness could be due to any kind of crypto-lawfulness have been examined and dismissed. Here too, then, we can find no lawfulness. But again this does not imply that there is no causality; it may be that lawfulness could not in principle be detected in this case by the observational methods available to physics.

CONCLUSION

The questions that we have been discussing are of importance not only for our beliefs about nature, but for the wider reason that people often suppose that far-reaching conclusions, even philosophical doctrines, can be derived from the conclusions of physics. Anyone familiar with contemporary writing and talking knows that people are readier to accept physics as true and to use it to construct a 'philosophy' than to investigate the method of physics, its presuppositions and their philosophical basis. In this chapter we have seen how physics is restricted by its own method, and cannot be expected to yield a full account of experience: it cannot deal with the fundamentals of rational thought and action, it omits consideration of qualities, of forms, of agents and causality. Accordingly the knowledge of nature provided by its theoretical interpretations is very limited; but these limitations

do not carry consequences outside physics. A philosophy cannot, then, be based upon physics alone; not only would it have to leave unexplained the basic assumptions of physics, but it would be absurdly limited in scope.

In the next few chapters we must attempt a fuller account of the method of science, of truth in science, of the presuppositions of science, and of the need of appealing to metaphysical method rather than scientific method in order to justify them.

PART TWO

Philosophical

CHAPTER IV

The Inductive Method and its Presuppositions

In the preceding chapter we have sketched some of the characteristics of physics that are entailed by its method. In this chapter we shall try to reach some conclusions about the status of natural science in general, by considering some aspects of the inductive method which is used by all the natural sciences. This inductive method consists in the combined use of systematic observation, generalisation from observed data to empirical laws, and formulation of theories whose logical consequences agree with the empirical laws. The theory of induction is concerned to examine the inductive method and the conditions which must be satisfied if it is to be valid. On the critical side, it lays bare these conditions; on the constructive side, we shall find, it must appeal to metaphysics; for science, it appears, cannot start without assuming a principle for which it can itself provide no evidence.

SCIENCE AND NATURE

We must first make a distinction between science as a self-contained unit, and science as a source of beliefs about nature. A scientist can, if he wishes, treat science as a unified scheme of observations, laws and theories, without considering its reference to nature. In this sense, as Whitehead has shown, science is autonomous, and needs no philosophical principles. If a scientist wishes to avoid all such presuppositions (except those of logic), he is entitled to regard science as a closed 'universe of discourse'; and it was Eddington's view that modern physical theory is formulated in accordance with this policy.[1] But we can also regard science not as self-contained, but as an approach to truth about nature, as referring to real objects. This would be the point of view of realist philosophers, and of most scientists.

[1] Cf. Chapter VI.

It is to this second approach that the theory of induction is relevant.

INDUCTION: PRELIMINARY REMARKS

Induction is distinguished first from deduction. Deduction is concerned with valid reasoning, from premisses whose truth is not being examined. Thus I may assume without discussion that no one ought to tell lies, and go on to deduce the consequences for the particular case of one who is writing a book. Or, as in geometry, I may assume a set of axioms that may or may not be true, and work out their consequences for particular cases. Or, as in formal logic, I may concern myself purely with the forms of valid inference (for instance, 'If *A* implies *B*, and *B* implies *C*, then *A* implies *C*'), disregarding entirely the truth or falsehood of the premisses in any particular instance. In all these cases the truth of the premisses is irrelevant to the validity of the deduction; one can make valid deductions from false premisses. Induction, on the other hand, is concerned with truth; it is one way of obtaining rational opinions about the world. It is a method for deriving generalisations from particular observations, and interpreting the empirical rules so obtained in terms of unifying theories. We have already considered, in Chapter II, some examples of inductive generalisation and theoretical interpretation, drawn from physics; the biological and psychological sciences likewise have their own types of law and of theory, reflecting their respective subject-matters.

Induction is the appropriate way of dealing with phenomena into whose laws we have no direct insight. I do not need induction to understand the principles of logic, for instance, which depend solely on insight into logical relations; nor again to understand the principles of morals, which depend on insights obtained through reflection on experience of life. But the necessary connections that control the behaviour of magnets, or the development of a duckling, or the influence of physiological factors on temperament—to take a few examples at random from the fields of physical, biological and psychological science—can be studied

only by the method of observation, generalisation and interpretation, which is called induction. Inductive method, then, is appropriate not to philosophy, but to the natural or empirical sciences. Indeed it defines the scope of those sciences. It is concerned with the coordination of phenomena. (The physicist's correlation of measured variables is evidently one version of such coordination.)

The theory of induction has for its field the whole method of natural science, the conditions for its validity, and the relation of its laws and theories to the observational evidence and to nature. It has been most fully developed, however, in connection with the most elementary generalisations on which all natural science depends, and is progressively less developed as one passes on to the more sophisticated laws of science and to theoretical interpretations. Each of these stages depends on the preceding stage: a theory is supported by the agreement of its consequences with empirical laws, which in turn depend on such basic generalisations as that there are definite kinds of matter. These latter generalisations are therefore fundamental to science and must be examined. Moreover, the dependence of science on metaphysical presuppositions is most clearly seen by considering this fundamental type of generalisation. In this chapter we shall therefore concern ourselves largely with this type, especially as some account of physical theories and their relation to the evidence and to nature has already been given in earlier chapters.

INDUCTIVE GENERALISATION: THE FORMULATION OF SCIENTIFIC LAWS

As we saw in Chapter II, a law derived from observation is a *generalisation based on analogy.* It is not just a summary of the data, but a construction, an interpretation, going beyond the evidence, and calling for some justification beyond the experimental observations and formal logic. We must examine these generalisations a little more closely. The proposition 'There are distinct chemical elements' will serve as an example.

Suppose we consider the evidence on which we believe that

there are definite kinds of matter—such as hydrogen, or iron. The evidence is obtained from particular bits of matter. Suppose we have an object consisting of pure iron. We do not, at the beginning of science, think of it as pure iron; for all we know it may be an inseparable mixture of elements. So we will simply call the object A_1. We investigate its behaviour in various circumstances —its interactions with other systems. Suppose we alternately heat it red-hot and allow it to cool. Then we can summarise our observations thus: "Each time A_1 was luminous, it was hot." (In modern physics, of course, we have a theory that asserts a necessary connection between temperature and luminosity; but at present we are considering the genesis of science, and the fundamental evidence for its conclusions.) The first stage of generalisation from this evidence is the assertion of a generalisation about A_1: "*Whenever* A_1 is luminous, it is hot." This asserts an invariable association of A_1's being luminous and being hot. The evidence for it is that A_1 has been observed on a few occasions to be both luminous and hot, and never luminous without being hot. Clearly the generalisation states more than the empirical evidence by itself warrants. We have asserted a law about all the conceivable occasions on which A_1 may be luminous—occasions which we do not intend to investigate, and could not in principle investigate. Nowadays we tend to think that the generalisation is obviously true, because we are so accustomed to the theory of stable chemical elements and its wide experimental basis. But no such generalisation is self-evident. Even though it may follow self-evidently from some theory, that theory itself gains its reliability only from generalisations of just the same kind.

We generalise in the same sort of way when we carry out the experiment quantitatively, measuring the brightness and temperature of the body and correlating their variations. For (exactly as shown in Chapter II) we then replace a set of observations by an equation connecting brightness and temperature; we may represent it by $B=f(T)$, meaning that B is functionally related to T, where B represents the quantitative measure of brightness and

T that of temperature. We assert a law of which we have examined very few instances. The quantitative law expresses a generalisation covering not only any occasion on which A_1 is heated, but any temperature (within limits) to which it is heated. It is thus a wider generalisation than the original qualitative statement; but the method of generalising is the same.

Suppose now that besides heating the iron object A_1 we also subject it to various other treatments; suppose we investigate its arc spectrum, its behaviour to chemical reagents, the relation between its density and temperature and so on. From each investigation we obtain a law or functional relation. We now repeat all this with other bodies. We find that some of them—call them A_2, A_3, A_4 and A_5—give results differing only trivially from those obtained with the body A_1. Others—call them B, C, D and E—give results that are very markedly different. On this evidence we generalise again, and assert an invariable association of properties (behaviour on heating, in the arc, towards chemical reagents and so on) for bodies of the *kind* A, represented by A_1, A_2, A_3, A_4 and A_5. We assert the existence of a *kind* of matter, A—known henceforth as 'iron'. Thus the belief in definite, separable and stable chemical elements depends on a further generalisation from the evidence. We have again gone beyond all the evidence that we could in principle obtain. We have stated a general empirical proposition although we do not propose to, and in principle could not, verify all its instances. We predict, for instance, that *any* bit of matter that shows the spectrum of iron will show the characteristic reactions of iron with acids; arguing that if an object exhibits some of the characteristics of iron it will exhibit the rest. Whenever the prediction has been tested, so far, it has been proved correct; but are we justified in extending the generalisation to all the cases in which verification has not been attempted? Anyone who thinks 'yes' without qualification should reflect on the confidence with which, in 1900, one would have predicted the result of any future determination of the atomic weight of electrolytic hydrogen, and on the great variation since demonstrated by the isolation of 'heavy' hydrogen. The

extension of generalisations to unobserved (and unobservable) cases is a matter that needs examination.

The same type of generalisation is concerned when we formulate physical laws, in the form of functional relations. And the biological and psychological sciences use the same procedure in formulating their basic generalisations. The process is called *induction by simple enumeration.* All scientists think that such generalisations are legitimate, that they are supported by the evidence, and can rationally be believed with a greater or less degree of confidence. They are certainly subject to correction; a single exception to the rule would compel us to seek a more accurate generalisation; but as far as the evidence goes at any time, it is held to support the current generalisation. As science progresses, these elementary inductions tend to be forgotten: we take them for granted and do not reflect upon the evidence for them. Yet the later inductive arguments presuppose the fundamental type and cannot have a greater likelihood than theirs. All science depends upon the validity of induction by simple enumeration.

The core of the problem of induction is the examination of the validity of this induction by simple enumeration—the formulation of general laws on the basis of a few observed instances. We have a few observations; as far as these data go, any association of properties that they suggest may be random and may not be exhibited next time we try the experiment. The iron object glowed only when it was hot, each time we tried the experiment. But that fact by itself is not a sufficient reason for generalising to future or unobserved occasions; from a few instances we cannot *deduce* a general law. The evidence is insufficient to support the conclusion. But we should be on stronger ground if we had independent reasons for believing that some generalisation must hold and that we have only to discover what it is; if we could show that there is sure to be a law and that we have only to find its form; if we were independently convinced that there is order in nature. Such a principle as this is not implied by the bare observations; nor can we appeal for support to the scientific world-picture, for that depends on generalisations of precisely the kind whose validity

we are discussing, so that we should be arguing in a circle. Formal logic, too, is powerless by itself to help us out of the difficulty, for it tells us only about the validity of arguments, not about empirical facts; it can clarify the conditions for our generalisation to be valid, but cannot tell us whether they are fulfilled.

THE ESSENTIAL STEP IN INDUCTIVE GENERALISATION: INTERPRETATION

It is clear that in scientific generalisation we go beyond the evidence, if by evidence we mean the bare data. What we do is to regard the observations not simply as data but as *signs*, indicating the form of some general law. We then interpret the signs, as best we can, to find this general law. In scientific work we very often speak of 'interpretation', and the word is apt, for to interpret is to read the meaning of a sign, to understand what is indicated by the sign. For instance, in language we use words as signs through which we communicate and understand thoughts. In using the inductive method in science, we treat our observations as significant of a law, and interpret them accordingly, formulating a law of which we think they may be signs. We shall say more about interpretation in the next chapter; here we must simply ask, what is the justification for our assumption that we may treat scientific observations as signs, and interpret them? We shall have to seek the justification of such a presupposition by methods other than those of natural science or pure logic. We must first, however, illustrate it further by considering more precisely the condition required for empirical generalisation to be legitimate.

INDUCTIVE GENERALISATION AS BASED UPON ANALOGY

Such generalising beyond the immediate evidence depends upon an appeal to analogy. It is analogy that suggests that, if an object X has some characteristics in common with the objects A_1, A_2 . . . it will have their other characteristics as well. The argument, if it were explicit, would run: 'A_1, A_2 . . . all have certain

characteristics; X is known to exhibit all those characteristics except one; therefore X will exhibit that characteristic also.' Or in more general terms: 'If a set of objects A_1, A_2 . . . have the characteristics $a_1, a_2 \ldots a_n, a_{n+1} \ldots a_{n+m}$, and an object X has the characteristics $a_{n+1} \ldots a_{n+m}$, then X will also have the characteristics $a_1, a_2 \ldots a_n$ and will belong to the class of A's. (The genesis of functional relations can similarly be formulated as generalisation based on analogy.) This again shows clearly that a kind of 'extrapolation' is concerned in every scientific statement, whether it is arguing from particular cases to another particular case, or whether it is generalising from particular cases to a general law. For the conclusion does not follow from the premisses by strict deductive logic. Indeed the argument has no force whatever unless we have independent grounds for believing that the analogy will hold. Even if we soften the conclusion to: 'It is *likely* that X will belong to the class of A's; and the likelihood of this is the greater, the smaller is n and the greater is $m+n$', we have still to explain why any such conclusion is likely; it certainly is not if we consider only the evidence cited.[1] For there might be objects with the characteristics $a_{n+1} \ldots a_{n+m}$, but with an infinite variety of additional characteristics totally different from $a_1 \ldots a_n$. To give any likelihood to the conclusion, we need, as a minimum, a condition stating that this variety is limited.[2] Alternatively we may state the condition as: 'Not all associations of characteristics in nature are random.' These statements express the presuppositions of inductive generalisation; they are precise forms of the statement that there is order in nature. Induction does not, incidentally, require a universal or rigid determinism; the proposition that it is likely that some parts of nature are to some extent law-abiding would be sufficient.[3]

[1] We shall have more to say of likelihood below and in the next chapter. Here it will be enough to note that a proposition is likely if there is evidence that supports it but does not make it certain.

[2] This is Keynes' principle of 'limited independent variety'. (Cf. his *Treatise on Probability*.

[3] Thus the theory of induction lends no colour to the view that science rules out miracles as impossible.

THE STATUS OF EMPIRICAL GENERALISATIONS

At this point it will be well to note certain other views about the status of scientific generalisations, and their differences from the present view. On one side it has been claimed that only individual observations are true, and that the generalisations derived from them are merely convenient shorthand, fictitious, and at best useful because they suggest new experiments. But this account appears to be invalidated by the structure of science itself, which consists largely of an explanatory scheme that succeeds in unifying the empirical generalisations. If these were mere fictions, it is hard to see how they could be brought into a logical unity. Such a positivist view does not seem capable of giving a satisfactory account of science as it is. At the other extreme, J. S. Mill sought to find a principle that would confer *certainty* on empirical generalisations. He hoped that this could be done by virtue of the principle of the 'uniformity of nature', which when combined with an empirical generalisation would (he thought) give a proposition that would be certain. It has often been pointed out that the attempt fails, even apart from the observed mutability of the conclusions of science. The argument is that if we supply, as a major premiss, some such proposition as 'Some generalisations are true in nature', we can turn the process of induction into a syllogistic argument and confer deductive certainty on an empirical generalisation. But suppose we make the attempt: if we try to frame a syllogism, it will have to run: 'Some generalisations hold in nature; *X* is a generalisation; therefore *X* holds in nature.' But the conclusion does not follow; we cannot conclude that *X* is one of the generalisations that hold in nature. It is in fact a mistake to try to turn induction into deduction. From the empirical data of science we can never derive a generalisation that is certain and depends only on our insight into logical relations, as does the validity of deduction. Natural science parts company here from formal logic and mathematics.

The view that we are developing is that scientific generalisations are neither certainly false nor certainly true, but more or

less reliable or likely, according to the evidence supporting them; that a scientific law claims a qualified belief, and the likelihood of its being true can be improved or worsened by fresh evidence. All such likelihood depends, too, not only on the bare data of science, but upon the legitimacy of assuming a principle which may be expressed in some such form as 'there is order in nature'. This is not, indeed, as Mill thought, a *sufficient* condition for a generalisation to be *certain*; but it is a necessary condition without which no empirical generalisation would have any likelihood—without which science could not begin.

THE ESSENTIAL PRESUPPOSITION OF SCIENCE: ORDER IN NATURE

The formulation of scientific laws, then, depends on generalisation on the basis of an argument from analogy; a process that depends on the assumption of an extra-scientific principle. This principle can be variously stated, as thus: the variety of independently occurring characteristics is not unlimited; or, not all associations of characteristics are random; or, some generalisations hold in nature; or, the behaviour of nature is not entirely arbitrary; or, some parts of nature are to some extent law-abiding; or, finally and more generally, there is some kind of order in nature. If science is to be possible we must have independent grounds for believing such presuppositions.

That the conviction of order in nature is in fact the mainspring of scientific research cannot be doubted. When a scientist thinks he is on the track of a new phenomenon, it does not occur to him to wonder whether it follows any law; he only wonders *which* law. Whitehead remarks that science depends upon 'the inexpugnable belief that every detailed occurrence can be correlated with its antecedents in a perfectly definite manner, exemplifying general principles. Without this belief the incredible labours of scientists would be without hope. It is this instinctive conviction, vividly poised before the imagination, which is the motive power of research: that there is a secret, a secret that can be unveiled'.

GROUNDS FOR THE BELIEF THAT THERE IS ORDER IN NATURE

This belief that there is order in nature is not a conclusion, but a presupposition of science; induction cannot begin without it. Yet neither formal logic nor the bare observations warrant it. It is in fact a metaphysical presupposition. (This, of course, does not imply that it is imaginary, or *a priori*, or that it is not derived from experience; but that it is to be derived from experience regarded from a different point of view and by a different method from that of science, as we shall see in Chapter VII.) It has been precisely one of the great concerns of the philosophers. Some of them, like Kant, have sought to answer on philosophical grounds the question: 'Does the succession of events in the inanimate world proceed according to laws?' Others, like Aristotle or Aquinas, would first answer the question 'Are all changes subject to necessary conditions or causes?', and subsequently discuss the connection of causality with lawfulness, showing that in given circumstances a given cause will uniformly produce certain effects. Our belief in the order in nature, then, is a metaphysical belief. Most of us hold it by common sense, but that only means that we have used an unformulated metaphysic, instead of relating the belief to an explicit system. We normally, and reasonably, take the belief for granted; but when we are considering the foundations of science, and the ultimate reasons why we believe its laws and theories, we must expose these presuppositions and examine the grounds for them. We must ask whether these conditions are fulfilled, whether there are facts which make them true; and this is a metaphysical inquiry. Metaphysics may be out of fashion with many philosophers, but its conclusions are indispensable to scientists, at least if they reflect upon the foundations of the scientific account of nature.

I am not here arguing in detail the metaphysical reasons for believing that there is order in nature; that would need a separate book. I will give only one suggestion. In *Science and the Modern World*, Whitehead puts forward a most interesting view about the

origin of the medieval philosopher's belief in a discoverable order in nature, a belief which he regards as an important element in creating a 'climate' suited to the great advance of science in the subsequent centuries. He says this belief 'must come from the medieval insistence on the rationality of God . . . the search into nature could only result in the vindication of the faith in rationality'; so that 'the faith in the possibility of science, generated antecedently to the development of modern scientific theory, is an unconscious derivative from medieval theology'. The metaphysical position corresponding to this historical view has been briefly suggested by Professor A. E. Taylor,[1] and it would be interesting to see it followed up, since it would give us grounds for believing not only that there has been but that there *will be* order in nature, an aspect of the matter that is often forgotten. I suppose the connection between order and the first cause[2] is somewhat as follows. If there is an intelligent direction of nature, there will be order in nature; if there is a law-giver, there will be laws. The first cause—whether one holds, with Aristotle, that its function is to impose order on a universe that would otherwise be chaotic, or, with Aquinas, that the universe depends on it completely for its very existence—is the source of every positive perfection; it must be infinitely wise, good and powerful. It will prefer order to chaos: and it will have the power to produce order. Therefore there will be order of some kind and degree in nature. On such grounds we could not indeed say that the order would be simple enough for us to find, nor that quantitative experiment would be a key to it; we could only conclude that there is order of some kind. But given the belief that there is order in nature, the actual existence of a body of natural science gives us strong grounds for believing that its generalisations are manifestations of this order; thus, although scientific laws do not of themselves prove that there is order in the material world, they do *manifest* an order in which it is rational to believe on metaphysical grounds. It seems, then, that the elusive reason

[1] In *Does God Exist?* (Chapter I).
[2] The term 'first cause' denotes God in so far as known by metaphysics.

for believing the presupposition of the inductive method might be found in the existence of the first cause.[1]

This account cannot, of course, claim to be more than the barest indication of the kind of consideration that seems important for progress. My point is that we cannot solve the problem of induction unless we consider the ontological conditions for its validity, to which far too little attention has been paid. The part of the problem of induction that belongs to critical philosophy has been clarified by logicians; the part that belongs to constructive philosophy has not received comparable attention. It is for metaphysicians to close the gap and so complete the work of the logicians.

THE IMPROVEMENT OF SCIENTIFIC LAWS

After the formulation of generalisations, the most important process in scientific method is correcting them in the light of fresh evidence. New observations may show an old generalisation to be inadequate, and it is necessary to improve it so that it fits the newly discovered facts. As a preliminary example of the improvement of a scientific generalisation, we can take the statement that hydrogen is a definite kind of matter—that all pure specimens of hydrogen produced in the laboratory will behave in the same way in any given circumstances. This was believed until a few years ago, when ordinary hydrogen was for the first time separated into two gases, 'light' and 'heavy' hydrogen, differing considerably in physical properties but very little in general chemical behaviour. Each of these gases can again be separated into two gases, differing only in certain recondite physical properties (ortho and para forms). The original hypothesis about hydrogen is now replaced by a more complex one about four different kinds of matter. The new law is more accurate, and on the total evidence it is more likely to be true—it is better supported.

There are several kinds of improvement that we can make in our beliefs (both scientific and other) in the light of new experience.

[1] Cf. Chapter VII and Appendix.

(i) I may simply come to understand a given statement better; thus I may come to understand more fully the meaning of '*X*' in '*X* exists'—I may be able to define *X* more completely. This is a progress from partial towards exhaustive cognition; the original statement, as understood by me, was not incorrect but incomplete. For instance, new properties of hydrogen might be discovered, and our conception of hydrogen thus enlarged. (ii) I may replace a vague statement by a more precise one; for instance, I may alter the statement 'This figure is an ellipse' to 'This figure is an ellipse of eccentricity *e*'; or specify a colour as 'carmine' instead of just 'red'; or determine more accurately the relation between the pressure and density of hydrogen. Here again the original statement was not incorrect, it was merely less determinate than the new one; yet the new one is an improvement, an advance from vague to distinct, from less to more exact or precise. (iii) I may replace an inaccurate statement by an accurate one, or at least a less inaccurate one. For instance, suppose I examine a geometrical figure superficially and say 'This figure is a circle'; on more careful examination I may have to say 'This figure is an ellipse'. Here the first statement is inaccurate; indeed, since the true statement is its contradictory ('This figure is not an ellipse'), the statement is, strictly speaking, false. But it is not so far from the truth as it might be, for there is something in common between it and the true statement. To be precise, there is a less determinate statement that includes them both and *is* true; namely, 'This figure is a closed conic section'—a closed conic section may be either an ellipse or a circle. Thus, although my first statement was inaccurate and had to be corrected, the improved statement is closely related to the old one. Whereas if I say 'I am hearing a noise' when I am not having any such experience, there is no such relation between this false statement and the true one, 'I am not hearing a noise'. The proposition 'I am hearing a noise' can be written off as false *without loss*; the proposition 'This is a circle' could not be simply rejected without loss, for, if one merely denied it and left matters at that, one would be failing to admit the true proposition 'This is an ellipse'.

Thus among statements that are, strictly speaking, false (meaning that their contradictory is true) there are two kinds. One kind can be denied and abandoned without loss, the other cannot. Statements of the first kind are just false; statements of the second kind may be called approximate. Obviously there are degrees of approximation, and some approximations are very poor; thus the statement 'Cats sometimes eat men' is very far from the truth, though it is distantly related to the true proposition 'Tigers sometimes eat men', because cats and tigers are members of the same family of animals. The more remote the connection with the true proposition, the worse is the approximation. We are not, however, interested in approximations that are inadequate on the evidence available to any educated person, but in approximations where progress towards the truth is desirable and difficult. We constantly meet statements which, as we say, have some truth in them; such statements are legitimate stages on the way to true statements, and if we learn from experience we spend much of our time correcting them. Correction commonly does not end with a demonstration that a statement is false and must be replaced by its contradictory; it very often includes a progress from less to more accurate. Thus a statement may be inaccurate and yet be an approach or an approximation to a true statement; its improvement is then not just a passage from false to true, but from less to more accurate. The reader will have no difficulty in supplying examples of such improvement from daily life, from history, law, and every branch of study.

Scientific work is much concerned with improving the accuracy and likelihood of generalisations. This is especially obvious in the earlier stages of a science, and indeed we can never be sure that a law (or a theory) is incapable of further improvement; we are warned by the extrapolations involved in formulating scientific laws, and by the revision to which they are in fact subjected, that we cannot be certain that they are finally true and not merely approximate. In general the revision of generalisations is forced upon us by new evidence; and when the new generalisation is based on wider evidence which makes the old one untenable (as,

for instance, the evidence for 'heavy' hydrogen), we have good reason to think that the new approximation differs less from the truth than did the old one, that the new statement is both more accurate and more likely to be true; an improvement has been effected.

The improvement of a scientific generalisation has commonly been considered as consisting in the elimination of irrelevancies, and consequently as depending on the disproof of one after another of the propositions compatible with the original evidence, narrowing the field with the hope of eventually leaving only one proposition, refined from all irrelevancy, as the true law. (Mill's famous canons of induction, for example, are principles for the elimination or invalidation of generalisations containing irrelevancies.) We note first that this procedure will only be of value if we assume the same condition as is assumed in generalisation, which we may quote in the form 'the variety of independently occurring characteristics is limited'; for otherwise the number and variety of propositions to be considered is infinite, and to disprove some of them does not at all reduce the field of likely candidates for the truth. Thus the improvement of the likelihood of laws seems to depend on the same assumption as the formulation of generalisations. Second, the approach by elimination has the advantage that each step is certain—a generalisation is invalidated with certainty by a single exception; it can thereafter be ignored, and attention directed to alternatives. But this suggests a criticism. Since this account considers propositions only as true or false, and omits to consider them as approximate, it obscures the fact that science commonly advances by successive improvements of approximate statements. Negatively, we have to recognise that there is no proof that any of the generalisations of science are perfectly accurate; but positively, we have to recognise that they are approximations to the truth, and demonstrably more accurate approximations than those they superseded, and so more likely to be true. Invalidation is only the reverse side of the positive improvement of approximate statements.

ATTEMPTED QUANTITATIVE VIEW OF THE IMPROVEMENT OF GENERALISATIONS

This progress seems to me to be qualitative, not susceptible of measurement; just as the credibility of a belief is not quantitative. That is why I have used the words 'likelihood' and 'improvement', avoiding the word 'probability' with its confusing quantitative associations.[1] However, perhaps from a laudable desire for increased clarity, attempts have been made to express quantitatively the improvement of generalisations, adopting the account which we have just criticised, and applying it to the mathematics of 'chance'. The argument might be simply stated as follows. Suppose that our evidence on a particular topic—say, the number of kinds of matter—is compatible with any one of a set of n propositions, and that there is no reason at first to prefer any one of these statements to another. (Thus, for example, before scientific chemistry began, there could be no good reason for preferring one answer to another.) Then, by analogy with the chance of drawing a given ball out of a bag containing n balls, the 'probability' of any one of the statements being true is said to be $1/n$. If now some of the statements, say m of them, are disproved by new evidence, the probability of each of the remainder will be increased to $1/(n-m)$. The probability formerly attached to the disproved propositions will (it is said) be transferred to the remaining ones. Thus the role of improvement is, on this view, to increase a numerical fraction representing the

[1] The word 'probability' is loosely used with three quite different meanings:

(i) The *likelihood* of a statement being true, on evidence inadequate for certainty; it depends on the evidence available.

(ii) The *chance*, in the sense of the mathematical theory of chance, of a given kind of hypothetical event; for instance, the chance of throwing a six at dice, if the dice is a perfect cube of uniform density and the throwing perfectly random. This is essentially the *ratio* of the number of kinds of event in a given class (throwing a six) to the number in a wider class (throwing a one, two, three, four, five, or six). This is one kind of numerical odds. The calculus of chance evidently depends solely on logical relations and is independent of whether or not it is possible to throw dice in the way imagined.

(iii) The '*frequency*' of a given kind of occurrence in the past; for instance, the fraction of sixes in an actual run of throws at dice, or the fraction of English males who died in their sixtieth year in 1915. This again is a ratio; but to determine it we need empirical evidence. It is thus a kind of numerical odds, but is quite distinct from mathematical chance.

probability of any proposition compatible with the facts so far known. As we revise our estimate of the number of kinds of matter—as it rises to the millions required by modern chemistry—we reduce the number of possible answers, and so increase the probability of any answer greater than the present number of kinds known.

I do not myself think that likelihood is the same as the 'probability' of the mathematical theory, nor that the essential features of the improvement of inaccurate generalisations can be represented quantitatively. It seems to me to be a qualitative progress, an intensive affair rather than an extensive one. But the conditions for the quantitative view to be of use are interesting. It cannot be of use, namely, unless we have grounds for believing that n is finite, that the number of hypotheses compatible with the facts is limited. In the instance considered, could we have any evidence that the number of kinds of matter is finite? Not from any observation, evidently; nor from formal logic; nor from scientific theory, for that must presuppose this or similar generalisations. The evidence would have to come from some source outside science. Thus the numerical view of probability at least illustrates the inability of science to give an account of the world without using extra-scientific presuppositions. The trouble with it is that it is based on the substitution of probability for likelihood. 'Probability' in this context means the same as 'numerical odds'; for instance, the probability of drawing a red ball out of a box containing equal numbers of red and blue balls is defined as the ratio of the number of ways of drawing a red ball to the total number of ways of drawing a ball (one-half)—or alternatively as the limiting value of the ratio of red balls to total balls after a large number of trials.[1] But neither of these definitions of probability is concerned with the relation of a statement to the evidence for it; 'likelihood' does not mean the same as 'numerical odds'. And I do not see how the degree of support given to a proposition by the evidence for it can be adequately represented by numerical odds; we ought not to let ambiguous words draw us into using false analogies. A

[1] Cf. note above, p. 67.

qualitative view of improvement seems accordingly to be preferable.

SCIENTIFIC THEORIES

As we saw in earlier chapters, a scientific theory is not deducible by formal logic from the empirical laws that support it. The argument is not of the deductively correct type, '*p* implies *q*, but *p* is likely on the evidence, therefore *q* is likely'—where *p* stands for an empirical law or set of laws, and *q* for a unifying theory. It is rather a sort of inverted form of this argument: '*q* (a unifying theory) implies *p*, *r*, *s*; but *p*, *r* and *s* are empirical generalisations that are likely on the evidence; therefore *q* is likely'. The conclusion does not follow from the premisses; the likelihood of the theory is therefore not a deduction from the empirical laws that are taken to support it. How then is the theory valid? The answer is parallel to that which we have given for empirical generalisations. Scientific theories are not deductions but interpretations (as indeed they are commonly called in science); these interpretations claim validity in as much as we are justified in regarding empirical laws as signs, pointing to the unified scheme or picture presented by the theory. The justification of the belief that empirical laws are signs of a more fundamental order requires at least the assumption that there is order in nature. It raises, therefore, the same question as the formulation of empirical laws and calls for the same principle; we are led again to the necessity of metaphysics.

CONCLUSION

We may summarise this chapter as follows. The elementary generalisations on which science, considered as a system of beliefs about nature, is dependent, are derived from observations by generalisation based on appeal to analogy; a process that is not deduction, but interpretation, treating observations not as bare data but as signs of a regularity; leading not to certainty, but to likelihood; not carrying its own credentials, but dependent on the assumption of a principle stating that there is order in nature.

The grounds for believing this presupposition must be sought in metaphysics, perhaps in the argument for the existence of a first cause. Scientific theories too are interpretations and require the same presupposition. An empirical generalisation can be improved, in the light of fresh evidence, in respect of completeness, precision and accuracy; the new generalisation is of course more likely to be true than the old, on the total available evidence.

It should be said that the view here outlined differs from many accounts of induction; firstly, in rejecting a quantitative view of the likelihood of propositions and of their supporting and improving, and in denying accordingly the applicability of the mathematical theory of chance; secondly, in noting the role of interpretation; and thirdly, in linking the theory of induction with metaphysics.

CHAPTER V

Science and Truth

IN the last chapter we were mainly concerned with the validity of generalisations, assuming the truth of the observational evidence on which we base them. In this chapter and the next we have to consider more radically why we believe *any* statement, what is the meaning of 'truth', and whether scientific and metaphysical statements can be known to be true. We want first a view of knowledge in general that will stand up to criticism—a view that avoids both an impossibly naïve realism and an agnosticism that is self-stultifying—and then applications of this view to natural science and to metaphysics. We have also to allay the suspicions that may be rising in the mind of the sceptical reader. Surely, he may be arguing, all that talk about agents and causes and metaphysics is very simple-minded. Are you not aware that Hume has subjected the notion of cause to searching analysis? Even realist philosophers mostly admit that we only have direct knowledge of reality in such elementary cognitions as 'I am now seeing a red patch'; beyond that, they say, all is belief, and subject to correction—what you thought was a red flower may turn out to be a cunning painting. In that case, how can you argue with any confidence about causes in nature and the rest? Would it not be better to rest content with summarising the data of sense, and not try to make any interpretations, especially of a kind that cannot be verified by experiment? Now I agree that there is a distinction between knowledge and belief, and that many of our everyday beliefs are no more than likely; I agree too that Hume does succeed in showing that the bare data of sense do not, by themselves and as such, strictly imply the causal interpretations we put upon them. But I think that it is nevertheless possible to justify both metaphysics and science, and that our confidence in some metaphysical conclusions can amount to

a rational human certainty. We must consider now our grounds for such statements.

EXPERIENCE AND INTELLIGIBILITY

We are acquainted with a flux of experience, a changing flow of data before our minds. But our experience is not of mere unfathomable chaos, not of just arbitrary succession, not of mere happening. We find in it entities that are more or less permanent —people, organisms, material objects. We think that we can identify the causes, or some of the causes, of some events; if a murder is committed, we seek the cause, namely the murderer; if I annoy a friend and he gets angry, I am sorry because I think that I am a cause of it. We discover, also, rules that seem to describe the behaviour of some material objects; in natural science such rules are investigated systematically. Our general experience is of order and intelligibility, and we build up a picture of ourselves and our situation that is more or less unified. Experience is not chaotic; there is something about it that makes it impossible to think of it as just 'happening'; if we reflect, we cannot think of it except as ordered, as intelligible in some degree.

Philosophers who are agreed on this conclusion have given two radically different interpretations of it. Realist philosophers would say that, if we find order, it is because there *is* order in things; if we find agents and causality, that is because there *are* agents and causality. They say that the mind is able to interpret what it finds without essential distortion; that it is able to understand things, in some degree, though no doubt under limitations and with difficulty; and that therefore any general characteristics of experience will reflect general characteristics of things, of reality. (If they are metaphysicians, they may go on to argue that a condition of the order in experience is the existence of a first cause; but that is not our concern at the moment.) Some such view as this seems to me inescapable, for reasons that will appear in this chapter, and accordingly I shall adopt it.

Other philosophers, however, would give an explanation that inverts the foregoing, and say that the order and intelligibility of

the world is due to our minds—to some peculiar properties of our minds, which compel us to think in terms of categories such as causality, and to impose those modes of thought on whatever data are presented by our senses. If we invariably impose the category of causality on the data that give rise to our experience, clearly we are sure to find causality when we examine the experience. But this theory seems to be untenable. On its own premisses, no reason can be given to support the assertion that some of the general characteristics of experience (such as causality) are due to some alleged properties of the mind, rather than to the things before us. In effect, the theory attributes the order in experience to systematic and radical distortion of the data by our minds. But we could never know that a fully systematic distortion was going on, because we should have no access to the undistorted reality for comparison. This explanation of order, then, appears to be an unsupported assertion. And there is another serious objection. If there is radical distortion when our minds work on the data presented to them, will there not also be distortion when our minds reflect upon experience in order to formulate a philosophical theory? If we say that we have arbitrarily imposed order when we find it in experience, can we deny that this interpretation itself has been imposed arbitrarily on the facts? If we deny that the mind can find truth in one of its operations, can we claim that it can find truth in another? The theory purports to give a true account of the way in which we arrive at ordered experience, but it seems to lead to the conclusion that no true account is possible. That is destructive of thought; if the mind is unreliable, it is no use philosophising. The realist view avoids these difficulties and enables us to give an adequate account of knowledge.

OUR KNOWLEDGE AND ITS DEVELOPMENT

Our knowledge (taking the word in a wide sense) includes many diverse elements. We need to make certain distinctions in a preliminary way, without as yet considering critically the relation of our knowledge or alleged knowledge to its evidence.

Some elements in experience we recognise easily as wholes or

unities—for example, paintings, poems, and the characters of our friends. Others we think of in more piecemeal fashion—for instance, the contents of to-day's newspaper, between which the connections are scanty. We all know what we mean when we distinguish intuition, or grasp of wholes, from discursive thought, or ratiocination. No doubt the difference is one of degree; a sonnet by Milton is grasped as a whole more readily than *Paradise Lost*, and a portrait is commonly more open to intuition than a baroque palace, though each was conceived as a whole; again, a science like chemistry, which at first seems to consist of disconnected observations, comes to exhibit a certain unity as one studies it. The distinction is none the less valid; in experience some occasions are predominantly occasions of seeing-as-a-unity, or intuition, and others are predominantly occasions of seeing-piecemeal, or discursive thought. Intuition characterises our approach to art; discursive reasoning characterises our approach to the sciences and the fields in which we rely most explicitly on reasoning.

Secondly, of some elements in experience we have a much more detailed picture than of others. For instance, we know some friends much better than others; we know some sciences better than others; we all have some special interests and some tracts of near-ignorance. We may distinguish, then, relatively complete or exhaustive cognition, and relatively incomplete or partial cognition. (This distinction applies both to intuitive and to discursive cognition.)

Thirdly, we find that some parts of our picture are very liable to need correction in the light of experience, while others are much less so. If I risk an opinion about to-morrow's weather, it is as likely as not to be proved wrong in the event; on the other hand, nothing will shake my conviction that I exist. Some statements I regard with certitude, others with confidence but not certitude, others with doubt, dissent or indifference. And there are various ways in which my view of such statements can be altered, since, as we argued in the last chapter, there are several ways in which our beliefs can be improved in the light of new

experience; they may become more complete, or more precise, or more accurate. Our progress in knowledge along these lines requires that we take up new attitudes with regard to the improved statements; doubt may give way to confidence, and confidence to certitude.

By 'certitude' and the rest I do not mean anything more than our state of mind when we consider a given statement. I do not inquire as yet whether we have rational grounds for certitude or not. Ideally, our certitude, or doubt, or what you will, depends solely on the evidence for the statements, and is then wholly rational. However, it is not only the mind that is concerned in assent, but the whole man; and so we find that emotions, or uncontrolled desires, may interfere with the free play of reason. Certitude, for example, as a psychological state may accompany not only occasions where the evidence justifies it, but also occasions where a statement is taken for granted without examination, or where obsession or prejudice prevents the consideration of the evidence. We must, in short, distinguish the *causes* of certitude, confidence and the rest, and the *reasons* for these attitudes. Ideally, however, the reasons—the evidence—are the sole relevant cause; and we shall assume in what follows that this is the case.

WHAT IS A TRUE STATEMENT?

So far we have merely described beliefs from the point of view of introspection; we have not examined the justification of our beliefs. We must also, however, attempt a critical assessment of our metaphysical, scientific and 'everyday' beliefs. We need to elucidate the evidence for these beliefs, and so decide which of them (if any) are certainly true, and which of them are merely likely; which of them are true (even though incomplete and inexact), and which are approximate. We are concerned, now, with the *truth* or otherwise of our statements, and (in the next section) with the evidence for them.

What do we mean by truth? In general terms, I mean the accordance of thought with reality. Or, since in thought we do not attend to the whole of reality at once, but work by means of

statements about some element of reality—some fact—to which we have turned attention, we may say that truth is the correspondence of statements with facts. If I say 'I am writing', and I *am* writing, the statement is true; if I say 'The patch that I see is blue and square', and it *is*, the statement is true. A fact either is the case or it is not the case; statements, or propositions, are about facts, and may be known, believed, disbelieved, asserted, doubted, denied, or merely considered. To put it crudely: facts are bits of reality, propositions are means by which we think about reality. Facts make our propositions true or false; truth for human thought is the correspondence of proposition and fact.

Perhaps such a definition requires some comment. It may be felt by some scientists that the definition is arbitrary, and that I might (or should) have defined truth otherwise; they would argue that for science 'true' means just 'simple', or 'coherent', or 'agreed', or perhaps 'communicable'. Any definition of the meaning of words is, of course, arbitrary to some extent; I have, however, adopted the correspondence definition for several reasons. One is that there are in fact instances of such correspondence of fact and proposition, as we shall see; and they are fundamental to all knowledge, including natural science. Further, this definition is merely a precise form of that used implicitly by nearly everyone, and therefore introduces the fewest possibilities of inadvertent error; whereas if 'true' only means, say, 'simple', there would be some odd consequences. For instance, there would be no obligation on me to assent to what I know to be 'true'—it is not necessarily the simplest view that corresponds to the facts; in historical work, for instance, the simplest view may be quite misleading; whereas there *is* an obligation to assent to what manifestly corresponds to the facts. If we define truth in terms of correspondence, then, we shall not be in danger of confusions from such sources; and we shall still be able to examine later the roles of simplicity, coherence, communicability and agreement in science. I shall therefore use the correspondence definition of truth, returning later to consider simplicity, coherence and the rest.

CERTAINTY AND LIKELIHOOD, KNOWLEDGE AND BELIEF

We are now in a position to examine more closely the question of the correspondence of statements with reality, and to consider the relation between our knowledge (using the word in the wide sense that includes beliefs) and the evidence for it. We have to ask such questions as: When, if ever, is certitude justified? Are all statements subject to correction in the light of fresh evidence? To answer these questions we shall have to examine our systematised knowledge from a different point of view; instead of the descriptive account hitherto given, in terms of our common-sense attitudes and procedure in growth of knowledge, we must attempt an account that analyses the ways in which knowledge is based on evidence.

We may draw two distinctions bearing on the treatment of the problem from this point of view. The first is the distinction of *certain* propositions and *likely* propositions. A proposition is certain if it may be recognised as true on the evidence; if the evidence excludes its contradictory. A proposition is likely if it is supported to a greater or less degree by the evidence, though its contradictory is not excluded; the likelihood of the proposition can be improved or worsened by fresh evidence. Certainty and likelihood are thus relations between a proposition and the evidence for it—between a given proposition and the propositions that support it. For instance, in physical science we suppose that the propositions 'S_1 is P', 'S_2 is P' . . . 'S_n is P' support the proposition 'All S's are P'; and in a law-court a barrister will support the proposition 'My client is innocent' with statements drawn from witnesses. The distinction is quite different from that of truth and falsity; it is concerned with the strength of the evidence for the truth of a statement. The truth of a true proposition may, on given evidence, be either certain or likely; even an untrue proposition may, on limited evidence, be likely, though it cannot be certain. The distinction is again different in kind from those between certitude, confidence, doubt, etc., since these are states of the thinker and may be affected by factors other than the evidence. But certitude is the rational attitude towards propositions that

are certain, and confidence is the rational attitude towards likely propositions, and so on. (I avoid the word 'probable', which is commonly used instead of 'likely', because it is ambiguous; as we have seen, it is used in the mathematical theory of probability in a quite different sense, which has nothing to do with our problem.)

A second distinction that we must note is that between *knowledge* and *rational belief*. 'Knowledge' is here used in a specialised and technical sense, not the general sense covering all cognition that we have used hitherto, in common with ordinary speech. If I am directly aware of a fact, so that the corresponding proposition is certain (in the sense already indicated), I am said to have *knowledge* (in the specialised sense) of the proposition. A known proposition may be immediately verified, by attending to it and to the corresponding fact. (I am not yet considering the question whether there are any such propositions.) If I do not know a proposition to be true by this direct awareness of the fact, but have other evidence for it, I can rationally *believe* the proposition. Thus a true proposition may be known or may be rationally believed. A known proposition is certain and cannot be corrected. The word 'knowledge' in this sense might with advantage be replaced by 'vision' or 'insight', were not the technical usage so well established. The context must suffice to show which sense is intended.

We must not pre-judge the question whether, in belief, the evidence can ever make the proposition certain, or whether it can only make it likely. This distinction of knowledge and belief is not the same as that of certainty and likelihood; though many philosophers would say that the classes of certain and of known propositions were coextensive, and also the classes of likely and rationally believed propositions. The distinction of certainty and likelihood is concerned with the *strength* of the evidence for the proposition; that of knowledge and rational belief with the *kind* of evidence (namely, whether or not it is concerned with direct awareness of the fact). We cannot, without examination, deny that there may be propositions for which the evidence is indirect,

but which are certainly true. For instance, it might be argued that the proposition 'Napoleon existed' is certain on the evidence available to an historian, though we cannot be directly aware of the corresponding fact. It would be premature, then, if we said that no belief was certain.

EVIDENCE AND ITS INTERPRETATION

We must now consider where, if anywhere, in experience we meet instances of knowledge, certainty, belief and likelihood, and what evidence we have that our systematised view of the world corresponds to reality. The reflective scrutiny of experience makes it clear (and this is one of the most important discoveries, or rediscoveries, of the modern realist philosophers) that there are occasions of knowledge in which a proposition can be known for certain. Such propositions include those that describe perceptions, introspections and memories; for example, 'I am now seeing a red patch' or 'This is to the left of that'; 'I am wondering whether the snow is melting'; 'I remember hearing a noise last night'. As Professor H. H. Price remarks, in his lecture on *Truth and Corrigibility*, it is difficult to formulate such propositions without saying too much, and so making the proposition appear to be one that can be corrected. For instance, 'I am now seeing a red patch' does not mean 'This material object has a surface that appears red'; one might conceivably be mistaken about the second proposition—the red patch might be due to some treatment of the eye, or of the optic nerve, and not to any red object. Nor does one assert that there is a red patch visible to other observers; the conditions of one's own observation (the colour of the incident light, for instance, and the state of one's eye) might be different from those of others. Nor does one assert that the word 'red' has the same meaning for other people. Thus, beyond such propositions as those cited, when, for instance, we refer to material objects, or 'public entities', we must admit that our propositions are not known but believed, and are often likely rather than certain. The 'thin' perception-propositions seem,

then, to refer to incommunicable facts. This does not make them uncertain; the use of agreement as a test of truth belongs to a much more advanced and sophisticated stage of cognition, when the systematisation of one's beliefs is far advanced. It is a mistake to suppose that the privacy of these pieces of knowledge makes them trivial. On the contrary, they are of very great importance, for two reasons. (i) They show that we are not limited to knowing copies or representations or impressions of reality. Recognition of them is a refutation of phenomenalism—the view, crudely speaking, that we can know only ideas and not realities. Knowledge is of reality, and we are not imprisoned inside our own minds, trying in vain to build a *pons ad extra.* (ii) They provide evidence for beliefs, and this evidence is certain. Thus, if we use them to erect a system of beliefs, the system will be grounded on certainty and not on mere likelihood. Since no combination of likelihoods can amount to certainty, this basis is of great importance for the status of philosophical systems, as well as for the beliefs of daily life. It is the 'thin' propositions that are known (in the strict sense) which save all our systems of rational beliefs from hanging in the air—which key our beliefs on to facts and not merely on to other beliefs, and so make it rational to consider the correspondence of beliefs with facts and not merely the logical consistency of beliefs. It is therefore of great importance that there are such propositions, which can be directly compared with facts (immediately verified by simply attending to the situation), and which are certain and not subject to correction.

These known propositions, then, provide the basic evidence for the beliefs of natural science, of metaphysics and of daily life. They support these beliefs, in some way not yet specified. In physical science, we rely ultimately on the sensation-propositions concerned in measurement, such as 'In my field of vision now two marks are coinciding'. This is knowledge in the strict sense; but the proposition that this supports, namely, that such and such a body has such and such a length, or that the reading on the dial is so and so, presupposes propositions about the permanence of standards of length and so on, and is evidently a belief, not

immediately known. My conviction that there is a brown table before me, with various books on it whose contents are familiar to me, is based ultimately on this sort of evidence. It is certain evidence, and that is a great thing; the trouble is that it is so 'thin', so far from exhaustive. I cannot deduce the existence of my table and my books and their contents and myself from such propositions, though some philosophers have tried to do so. The data that I get by looking at a penny from every angle are not enough for me to deduce the truth of propositions about the penny of which I am convinced—that it is a round, hard continuant with certain causal properties. The evidence of my senses does not enable me to deduce that the penny has certain dispositional characteristics like dissolving in nitric acid to give a blue solution, that it carries an image of the King's head and will pay half my tram fare. I am convinced of all these propositions, but not because I can *deduce* them from the 'thin' propositions of which I have certain knowledge. Rather it is because I *interpret* the evidence provided by these propositions. They are signs through which I am in contact with reality; my thought attempts to grasp some intelligible fragment of reality, some thing or some fact or some generalisation, by interpreting these signs.

What does 'interpretation' of sensation-propositions mean? It seems to mean that, treating the sensations as signs, we grasp (to some extent) that which they signify. We find analogies for this in other kinds of interpretation. The inductive method supplies one instance; as we saw earlier, an empirical law is not deducible from the data, nor is a theory deducible from the empirical laws; they are interpretations—guided, it is true, by our conviction of the general proposition that there is order in nature, but still interpretations and not deductions. It is somewhat similar with art and poetry and music; a unity is expressed, by signs, and we have to interpret the signs to find that unity. These, then, are some analogies for the process that occurs when we put together sensations and say we are aware of a *thing*; when we interpret the signs and reach some knowledge, however incomplete, vague or inaccurate, of the thing.

I do not say that we at once and without further effort apprehend the nature of the thing; far from it. What we attain is no more than a prima facie belief; not until a vast deal of data has been integrated into such beliefs can we begin to think we may be right. No doubt many of my interpretations are uncertain and open to correction; indeed I do improve them as life proceeds—all of us are constantly correcting beliefs in the light of the evidence provided by fresh experience, replacing less accurate beliefs by more accurate ones. This is true of everyday beliefs just as of scientific beliefs. There are, however, many everyday beliefs for which the evidence rapidly becomes overwhelmingly vast and cogent, such as (to take some trivial examples) that my house is three stories high, or that oak trees exist, or that Britain is an island, or that Napoleon is dead. The difficulty about formulating the evidence for such beliefs is that it is too vast; we cannot even enumerate all the sensations that support a well-established belief of daily life. Such beliefs are like the empirical generalisations of science, in that they are interpretations of evidence obtained through the senses; but there is a great difference in the weight of the evidence. From the present point of view—that of the relation between evidence and beliefs—the main difference between the evidence for common-sense beliefs and that for scientific generalisations is that evidence for the former is on the one hand usually less explicitly expressed, and on the other hand much more extensive, when it *is* so expressed, than the evidence for the beliefs of science. The scientific evidence for an empirical law is sometimes so scanty that it can all be recorded in a few pages; not until we reach generalisations like the second law of thermodynamics do we reach a weight of evidence even approaching that for a well-established belief of daily life. This may seem shocking to those who regard the inductive method as the top and summit of all reasoning; but if we examine it, we seem driven to the conclusion that scientific beliefs have the advantage over such common-sense beliefs only in that the evidence for them is easily made explicit, and that the beliefs can easily be corrected in the light of fresh evidence.

All the time, then, I am building up beliefs, about a great variety of entities and their qualities and relations, and generalisations about them. These beliefs build up into a set that is logically compatible. A belief may, moreover, be supported by other beliefs. Beliefs in fact are not isolated, but to some extent form a unity. Some of our beliefs are logically interdependent; some presuppose other beliefs. When I go on a walking holiday, I presuppose the quasi-permanence of Britain and of her roads and villages; I presuppose, too, the accuracy of the instruments of the map-makers and the reliability of the geometry presupposed in their triangulation. I have evidence for each set of presuppositions, but in the event they also support one another. The countryside and the map mutually check my beliefs about them.[1]

Again, it is important that the evidence for my beliefs is largely indirect. For instance, the belief that Britain is made up of islands is presupposed in my thoughts and discussions on travel, correspondence, trade, defence, holidays, and a host of other topics; and when I have acted on the belief I have never been brought up short by a contradiction. I believe that if I travel far enough in any direction I shall come to the sea; and if I try it, I am not disappointed. The evidence is not catalogued, but it is enormous; it constitutes a 'unity of indirect reference', in which the belief that I live on an island is supported not by direct verification but by indirect evidence of a quantity and variety that is beyond enumeration. If it were not true, I should find out by being brought up against some fact at variance with it.

Beliefs, then, are not like isolated particles; rather, they are like strands in a web. The 'thin' propositions that are the ultimate evidence for our beliefs are like the molecules that make up the fibres that compose the strands. A fibre, or a whole strand, may break, but the molecules remain intact; just as our beliefs, though built up by interpretation of unbreakable propositions, may be disproved and shown to need correction. Some of the strands in

[1] I avoid the word 'coherent' since it is ambiguous; it may refer to a set of propositions that logically entail one another, or it may simply mean logical compatibility of propositions, or it may even refer to the relation between fact and proposition here called correspondence.

our web of beliefs depend upon others for support; for instance, scientific generalisations depend upon the belief that there is order in nature. Some of the strands are essential to the structure of the web, like the main strands of a spider's web; without them the whole web would collapse. The analogy breaks down here because no strand can be infinitely strong, whereas a belief can be certain. For instance, if the proposition 'I exist' is false, I cannot make head or tail of what is happening at the moment as I write. If I try to think it is false, I can make no sense of my experience; I cannot interpret the sensations that convince me that marks are appearing on paper as a result of my volitions and actions, nor the introspections and memories that convince me that I am trying to write down in order the beliefs that a continuant 'I' has considered over a period of years. If 'I exist' were false, the beliefs of our everyday life and experience would be unsupported myths, and they would be disproved instead of being supported by experience; life would be wholly unintelligible. It is not merely that the system of our beliefs would become incoherent, but that all the facts on which it is based would be ignored. If I do not admit that I exist, I must abandon hope of giving a reasonable account of any of my experience. I shall have to behave like Cratylus, who was so convinced that discussion was useless that he would not acknowledge questions except by waggling his finger. At a common-sense level, then, there are beliefs that are certain, and not subject to correction in the sense of being inaccurate. They may be incomplete or inexact, but their falsity is excluded by the evidence.

METAPHYSICAL STATEMENTS

Reflection, moreover, reveals to us more abstract propositions that are equally essential to the web—essential, that is, to the interpretation of any experience. Though they may not be obvious, the whole web depends on them; perhaps we may liken them to its supports, without whose unobtrusive strength the web would fall to the ground. These are the metaphysical beliefs, presupposed by science and art and history and daily life; some

of them will be indicated in Chapter VII. We cannot make sense of experience without (to speak technically) the categories of substance and causality and the contingency of the objects of experience. Such beliefs may well be subject to improvement, in the sense that they can be made more complete or more precise; nevertheless I should maintain that some metaphysical statements are certain—they could be incomplete or inexact, but we can have rational certainty that their contradictories are excluded by the evidence. We shall discuss further in Chapter VII the criteria for such statements; but evidently the closer one keeps to what is essential to the intelligibility of all and any experience, the more certain are one's conclusions.

SCIENTIFIC STATEMENTS: TRUTH IN SCIENCE

In this and the preceding chapters we have given some account of scientific statements. The empirical laws of science, we have argued, are supported ultimately by evidence consisting of sensation-propositions that are known in the strict sense; they are interpretations of the evidence, and these interpretations require also the presupposition that there is order in nature, a proposition which it is rational to believe on metaphysical grounds. The theoretical interpretations of these laws are constructions, from which may be deduced propositions which are compared with the empirically determined laws; they are supported if there is agreement, and require improvement if there is not. These theoretical interpretations have commonly been associated in the older physics with models; but such models are simply analogies, more or less complete, embodying the equations of the theoretical scheme, but having no explanatory value of their own. Such, in summary, is the account of science that we have developed so far. If this kind of view be accepted, it is evidently meaningful to speak of the 'truth' of scientific laws and theories, in the sense of the correspondence of these statements with reality. A given law may or may not correspond with fact; it may be more or less accurate. A given theory may be more or less significant of reality; it will be more or less capable of improvement. Physical

models, too, are brought into relation with the correspondence of fact and statement, through their connection with theories. Thus the whole scheme of physics is readily related to the correspondence definition of truth; it is meaningful to ask whether an empirical law or a theory is true in the sense of corresponding with reality—however difficult it may be to form an opinion on the precise degree of accuracy and likelihood of a law, and however complex and obscure may be the way in which a theory is significant of reality. The inquiry into the truth of scientific statements fixes attention on the accordance or non-accordance of our scientific schemes with reality; it poses, therefore, questions that are not only sensible but of the greatest importance. These questions are not necessarily present explicitly to the scientist's mind in the actual pursuit of science—as we have mentioned, it is possible and legitimate to pursue science as a systematisation of observations and theories, omitting consideration of its truth —but they are highly relevant to any scientist who is interested in the status of science as a form of knowledge.

It is thus neither necessary nor desirable to reject the correspondence definition of truth, when discussing scientific statements, in favour of a definition in terms of coherence, or simplicity, or agreement, or communicability between different observers, as has from time to time been suggested. Nevertheless, these characteristics of scientific statements, which have sometimes been proposed as criteria of their 'truth', are important, and we must examine them; scientific schemes are in fact more or less coherent, simple, agreed and communicable. But though these attributes are required of any scientific scheme, they are not the same as the truth or accuracy of the scheme (its relation to facts), nor are they the same as the likelihood of the scheme (its relation to evidence). As we shall see, however, these characteristics are of interest, in different ways, in *testing* the truth of a scientific statement and estimating its likelihood. With this preamble we can consider these attributes of scientific statements in turn.

(i) '*Coherence*' is a word with several meanings. In the present context it seems to denote the relation between an empirical law

and a theory from which it may be deduced (within experimental error); that is, the relation of deducibility or strict implication. Coherence in this sense is the relation between laws and valid theories. Clearly this is an important relation—we have dealt with it at length—but it is not the same as the relation between laws (or theories) and reality, which is what we mean by truth. Coherence is, however, *evidence* for the truth of the theory, which consists in correspondence with reality. If then we were to define truth as coherence, we should be confusing two quite different relations, both of which are of importance, on our realist analysis, but in quite different ways; one a relation between propositions, and the other a relation between proposition and fact.

(ii) *Simplicity* is a notion that has misled some writers, who have written as though we could be certain, *a priori*, that the behaviour of nature must be simple, and that the simplest law is necessarily the true one. In fact, we have no rational grounds for such a view, and it seems likely that such simplicity as is manifested by science is due to the fact that scientists have naturally turned their attention first to relatively simple phenomena. Simplicity is not the same as truth, nor is it even a test of truth or accuracy. For instance, Einstein's formula for the orbit of a planet is more accurate than Newton's, and it is more complex. The simple view in science (as in history or politics) may be far astray. The reason why simplicity is a virtue in the scientific scheme is that it facilitates the work of checking a theory and devising new experiments to test it. It is useful in handling a given theory, but not as a direct means of judging the accuracy of two different theories.

It may be objected that if two theories 'save the phenomena' equally well, scientists choose the simpler. This may be admitted, but I do not think there is any reason to suppose that the simpler view is the more significant of reality; it is chosen because it will the more easily lead to new experimental tests and a new advance in which both theories will be replaced by a better one. The rule 'Do not use a complex law or theory when a simple one will do' is not a criterion of the truth of the law or theory concerned, but a condition of convenient manipulation; we may be forced by

facts to adopt a more complex view, but we will not do so unless we must.

The case of the Ptolemaic and Copernican systems is of interest here. The Ptolemaic system, in which the earth was represented as stationary and the heavenly bodies as moving about it in cycles and epicycles, was more complex to handle than the Copernican, in which the sun was taken as stationary with the earth moving round it; but the two systems 'saved the phenomena' with about the same accuracy. If there were no other evidence, we should be justified in using the Copernican account in our computations, to facilitate the work; but we should not be justified in holding that in its physical significance it was necessarily an improvement on the Ptolemaic account. In point of fact, both accounts make the important mistake of failing to stress that motion is relative. The question whether the earth goes round the sun or the sun round the earth is wrongly posed; the answer depends on the point of view of the observer—to an observer on the sun the earth appears to revolve, to an observer on the earth the sun appears to revolve, because the motion is relative. The real question is whether the earth is a unique body or whether it is subject to the same dynamical laws as the heavenly bodies; and in particular, whether its motion relative to the sun is similar to that of Mars and Venus and the other planets. The Copernican computations show simply that we get just as good agreement with observation if we assume that the earth is dynamically on the same footing as the planets, as if we assume that it is dynamically unique. (This is its true significance in the controversy of Galileo's time, over Aristotle's view that heavenly bodies were subject to laws quite different from the 'sublunary' laws that hold on the earth.) It is only in virtue of other and independent astronomical evidence (such as Galileo provided by his discovery of the 'mountains on the moon' and of Jupiter's moons) that we can decide for the former view.

(iii) *Agreement* between different workers is a favourite test of the reliability of scientific research. Scientists are always happier about a piece of experimental work when it is verified by more

than one observer; and when a new theory is put forward the scientific world awaits the agreement or disagreement of those qualified to examine it. Evidently a contradiction between two views *about a given topic* means that one view or the other is inaccurate or false; so that lack of agreement is a negative indication, warning us that either view may be false—provided we are sure that the two views are really about the same facts. It would, however, be admitted, I think, that agreement is not a necessary condition of truth—Cavendish's experimental results were true before they had been repeated, Newton's theory of gravitation was no less true before it was shared with Halley. Agreement, indeed, makes no difference to the relation between statement and fact; it does not constitute truth, nor by itself does it guarantee truth. The great significance of agreement seems to be that it increases our confidence that the evidence is *relevant*, that it has been properly assessed. It indicates that the experiments have been carefully done, so that the results really refer to the phenomena they claim to refer to, and not to some irrelevant anomaly; and that they have been interpreted in the relevant way. Agreement, then, appears to be an assurance against inadvertent error; it helps to ensure that the reasons for a given conclusion are the real causes of our belief in that conclusion.

Agreement has, however, another function, and a most important one. It constitutes evidence that different scientists think the same questions important and worthy of attention. If different people attend to different evidence, supporting different conclusions, about different phenomena, they will not reach agreement —not because either of them is wrong, but because they will not talk about the same topics. (Agreement, we see again, is not a necessary condition of truth.) The fact that agreement is very common in science indicates that on the whole scientists are agreed on the problems that are important and the evidence that is relevant. This community of opinion colours the whole practice of science, and has been a major factor in its rapid advance. The prestige of scientific method resulting from the successes of science has sometimes led people to think of agreement as the great and

fundamental test of truth, and to taunt philosophers with their lack of agreement. But disagreement does not by itself indicate that one of two parties must be wrong; they may be attending to different evidence, or they may consider different questions important. In philosophy the diversity of evidence that might be thought relevant is very great, and the questions that may be asked reflect many different points of view. We should be cautious before arguing from the (alleged) lack of agreed philosophical 'results' to the falsity of all philosophy.

(iv) *Communicability*, like coherence, is a word with several different meanings. Scientific statements must evidently be capable of being communicated from one scientist to another, since science is necessarily a social enterprise (because agreement between observers is a check on inadvertent error, and because life is too short for one man to construct the whole system of science). Science therefore cannot deal with statements which, however certainly true, refer to private situations; for instance, 'I am now seeing a dark line on a white field'. It is only interested in data and conclusions that are in principle accessible to any competent observer, such as 'This pointer is now opposite division 36 on the scale', or 'This alloy has a melting-point of 360° C.' —propositions that are common property in a way that sense-data are not. And this brings us to a further requirement, characteristic of modern physics. The finite and constant speed of light introduces complications, as we have seen, when observers are in motion relative to one another; they will not get the same values for the apparent distance and time between a given pair of events; but their observations can be harmonised by using a suitable 'transformation' (the Lorentz transformation), and they will all get the same result for the 'space-time interval' defined by relativity theory. The space-time interval is common property in a way that the observed apparent distances and times are not; it is 'communicable' in a new sense. Fundamental physics is, it appears, now formulated in such a way that its statements are common to all *conceivable* observers; its statements are communicable in this special sense. (We shall return to this point in the next

chapter.) Evidently this characteristic of the propositions of fundamental physics is an important one; but it does not constitute the truth or falsity of those propositions (the relation between proposition and fact) nor their likelihood (the relation between proposition and evidence). It simply defines the kind of propositions admissible in fundamental physics. Only statements of this kind can be verified by all observers; but that does not mean that they are the only true statements. Communicability, then, does not supersede correspondence as the definition of truth.

A scientific statement, then, besides being supported by evidence, must be communicable (in the sense of verifiable by any observer), if it is to form part of science at all; and it must be simple enough to be dealt with by current logical techniques, if it is to be manageable. If in addition it is agreed upon by competent workers, we have an additional assurance that it is not vitiated by inadvertent errors, and that it is relevant to the progress of science. These characteristics of scientific statements are all important in relation to truth; they are bound up more or less intimately with the *verification* of scientific statements. They do not themselves constitute truth (there is no insuperable difficulty in defining 'truth' for scientific statements in terms of correspondence); but each of them is concerned, to a greater or less degree, in the business of finding out which statements are true.

CONCLUSION

A philosopher might complain that in this chapter I have gone much too fast; I have not given a proper account of many views that are controversial. This of course is true; but I have tried to give a reasonable account that is in the line of progress, and is worth improving. I have tried to steer a realist course among the shoals of phenomenalism (in the argument about knowledge and belief), of sensationalism (in the argument about interpretation), and of idealisms deriving from Kant (in the argument about order and thought). My view is that while the modern realist theory of knowledge is most valuable, in the forms in which it is commonly stated it does not go far enough, and that in particular

the supporting and correcting of beliefs has received too little attention. The best treatment of the problem that I know is the theory of interpretation,[1] which shows how we can be rationally certain of some beliefs and gives us a basis for metaphysics. In some such way we can make contact with the great realist metaphysical tradition (part of which we shall meet in Chapter VII), which runs from Aristotle through the Arab philosophers to Albert the Great and Thomas Aquinas, and thence in many streams of Western thought. We should, I think, hope for nothing less than a synthesis of the modern precise approach to epistemology with the traditional approach to metaphysics; though such a work of synthesis is not to be achieved overnight.

[1] Cf. M. C. D'Arcy, *The Nature of Belief*, especially Chapter VI.

CHAPTER VI

Science and 'a priori' Knowledge

IN recent years, more than one distinguished scientist, and in particular the late Sir Arthur Eddington, has come to believe that some of the theories of current physics are independent of the observations that historically led to them, and do not need experimental support. If this be true, all the pother about inductive generalisation and its dependence upon metaphysics is unnecessary, for without any experiments we could derive the fundamental theories of physics, and hence by deduction the laws hitherto discovered by the laborious method of induction. The claim therefore needs attention here. Eddington developed a theory of the fundamental laws and constants of physics which is expounded at length in his *Relativity Theory of Protons and Electrons* (1936) and in his posthumous *Fundamental Theory* (1946); he presented a relatively non-technical account in *The Philosophy of Physical Science* (1939),[1] and it is to this account that we shall refer in the course of this chapter. It is too soon to attempt a final estimate of the significance of Eddington's work, which has not yet been thoroughly sifted by expert opinion, though a beginning has been made.[2] But his position needs examining, if only in a preliminary way. This chapter will necessarily contain more references to physical technicalities than the rest of this book, but such references will be kept as simple as possible and need not deter the less physically minded reader.

THE SCIENTIFIC PART OF EDDINGTON'S THEORY

Eddington's results. Without pre-judging the methods by which they are reached, Eddington's results are briefly as follows. He

[1] Hereafter referred to in footnotes as P.P.S.

[2] Cf. E. T. Whittaker, (*a*) 'Some disputed questions in the philosophy of the physical sciences', *Proc. Roy. Soc., Edin.*, vol. lxi, p. 161 (1942); (*b*) 'Eddington's theory of the constants of nature', *Mathematical Gazette*, vol. xxix, p. 137 (1945).

claims that it is possible, solely from the consideration of the ways in which physical observations are made, to deduce both the mathematical forms of the fundamental laws of modern physics and the numerical values of certain numerical constants that occur in them. These fundamentals differ from those of nineteenth-century physics because of the introduction of relativity theory and quantum theory. The fundamental laws include Einstein's law of gravitation and the relativistic wave-equation for an electron. The fundamental constants can be reduced to four fundamental numerical ratios—pure numbers; these are the ratio of the masses of the proton and electron, the 'fine-structure constant', the gravitational constant, and the 'cosmical constant'. (The cosmical constant is the number of particles in an Einsteinian universe composed of hydrogen and satisfying the requirements of quantum theory.) The values obtained by Eddington are in good agreement with those derived from experiment.

The status of these results: preliminary remarks. Clearly such calculations are of the greatest interest. But in deciding their status much depends upon exactly what propositions form the basis of the deductions. In particular, it appears that these propositions include (at least in general form[1]) the fundamental principles of relativity and of quantum mechanics, whose basis is empirical, and which in fact are inductively established, depending on a vast amount of experimental work. The experimental basis of relativity is, briefly, that numerous experiments have shown that the velocity of light is finite (so that it is not possible, even in principle, to observe an event at exactly the moment it happens); and that experiments such as those of Michelson and Morley lead to the conclusion that the velocity of light has the same finite value for all observers who move relative to each other with uniform velocities. The experimental basis of quantum mechanics is that results on radiation from luminous bodies, on the interaction of such radiation with matter, and on various other phenomena, lead to the conclusion that energy can only be transferred in

[1] Professor Whittaker's view is that Eddington assumes merely general forms of the empirical discoveries of modern physics, and deduces the exact forms of the laws and exact values of the constants. Cf. footnote 2 (*b*), page 93.

discrete quantities; or more accurately that only such discrete transfers can be observed; so that to carry out any observation causes a finite disturbance of the system observed, and we cannot in principle make exact predictions of the state of the system.

The recognition that Eddington's conclusions rest upon propositions whose status is that of inductive generalisations (however brilliant), depending upon experimental data (however extensive), leads to a view of their significance markedly different from that of Eddington himself. As we shall see, he calls his approach an 'epistemological method', and seems to claim a more than inductive certainty for the results. This claim might be justified if the results were deduced solely from propositions whose truth or falsehood is independent of particular experiments—for instance, that material objects are extended and that we can measure distances; that is, if the results were deduced solely from a consideration of the method which characterises physics, namely, the restriction of observations to inanimate matter and to its measurable aspects. But it appears that Eddington's results are not deduced from this basis alone, but require also propositions which are dependent upon the results of particular observations. On this view, the significance of Eddington's results is that the particular forms of the fundamental laws of physics, and the particular values of the constants that occur in them, can be deduced, using symbolic logic, from a consideration of the general metrical method of physics, *plus* certain methods which by reason of their success are always used in interpreting experimental results, *plus* the inductively based propositions of relativity and quantum theory. That this is a very remarkable contribution to science is obvious. But the point here is that it seems incorrect to claim for these results a certainty greater than inductive. Eddington's work, on the present view, has the status of a unifying theory, whose likelihood is improved by every deduction from it which accords with experiment.

Methods of physical interpretation. Besides the theories of relativity and of the quantisation of energy already referred to, and the proposition that all physical observations are measurements, there

is a third group of propositions that Eddington uses in his deduction of the fundamentals of modern physics.[1] Their status is peculiar at first sight, and Eddington's formulation of them seems particularly valuable. They may be summarised by saying that it is considered legitimate and useful in modern physics to interpret observations in terms of mathematically defined entities and relations, such that the whole is no more than the sum of its parts, which parts have a certain degree of permanence and are precisely alike except in respect of certain relations to other entities. In physical interpretation an analysis is *de facto* regarded as incomplete until this stage is reached. These methods are familiar enough in certain applications; all electrons, for example, are regarded as identical in properties, though occupying different states. The way in which protons and electrons are reduced to units identical except for being differently related to the general distribution of matter in the universe[2] is less familiar, but it is a good illustration of the same methods.

Fundamental theory in modern physics, according to Eddington, is explicitly based upon these methods of physical interpretation. But it is a mistake to jump to the conclusion that they have therefore a philosophical status, let alone that they are known *a priori*, as Eddington seems to do when he speaks of them as engrained frames of thought, imposed by the intellectual equipment of physicists. Several points need elucidation here. First, Eddington seems to confuse various senses of the term '*a priori*', one of which senses is peculiar to himself; of this more later. Secondly, these methods of interpretation appear to derive their validity from the fact that they have been found successful in formulating theories whose logical consequences are in agreement with experiment. Therefore they are supported inductively, though less directly than the various theories which exemplify them (which in turn are supported inductively, though less directly than the empirical generalisations which they interpret, such as the gas laws). This seems a far more convincing account

[1] P.P.S., Chapter VIII.
[2] P.P.S., p. 124.

than the unsupported statement that they are forms of thought imposed *a priori*. The formulation of them is a part of the general evolution of science, in which empirical discovery and theoretical interpretation are closely connected. Thirdly, these methods of interpretation are not philosophical principles, as is obvious from what has been said; yet Eddington seems to believe that they are. This is perhaps an example of a failure to realise that philosophy is not restricted like physics to the consideration of the metrical aspects of the inanimate world, and that its problems are different from those of physics (some of them indeed being concerned with the presuppositions of physics). The root problem which physics presents to philosophy is not to decide which physical principles are true, but to decide what is the validity of empirical generalisations based on a relatively small number of measurements none of which is exact, and what is the validity of the mathematical theories developed so that by deduction from them one obtains equations agreeing with the empirical generalisations. This, as we have seen, is the philosophical problem of induction, but its existence is not always suspected by scientists who believe themselves to be writing about the philosophical basis of science.

Use of symbolic logic. The last element in Eddington's work is the use of mathematical logic. Mathematical or symbolic logic, like all formal logic, is concerned with the forms of valid inference, irrespective of the truth of the premisses; and it has *a priori* validity within these limits, in that our assent to valid reasoning depends not on evidence derived from experience but on insight into logical relations. Eddington introduces the 'mathematical theory of structure', by means of which he is able to carry out in a precise manner the general methods of interpretation outlined above. He introduces what he calls a 'structural concept of existence' and a 'structural concept of relation'. These really amount to algebraic symbols which can only possess certain definite values, which can be so interpreted as to correspond with certain of the characteristics of existent and related objects—much as in Boole's two-value algebra the two possible values of the variables can be interpreted as corresponding to 'true' and

'false', and the symbols themselves as corresponding to propositions.[1] He calls them 'structural', presumably because they are analogous to the symbols that occur in the mathematical theory of groups, which deals symbolically with structure. The usefulness of these symbols is that of symbolic logic generally; by their aid Eddington is able to handle problems that would otherwise be too complex.

Modern physical interpretation and the autonomy of physical science. Eddington himself does not mention this reason for the introduction of the mathematical theory of structure, but stresses rather the fact that it is common to many minds, whereas sense-data are private to the individual. He emphasises that fundamental physics is now formulated explicitly in terms of structure-theory in order that it may be common property. This leads to a most interesting situation in connection with Whitehead's views on the independence of philosophy and natural science. The reason why Eddington's emphasis is laid where it is, seems to be that he regards sense-data not, as a realist philosopher does, as signs of something other than the cognising mind, but merely as elements whose origin need not be discussed but which have to be integrated with an interpretatory scheme of laws so that the resulting synthesis of experience may be as 'coherent' as possible. This treatment of sense-data seems to be harmless in a scientist while he is concerned only with science—that is, so long as he does not venture out as a philosopher. Whitehead has shown that scientists can, if they will, proceed without paying attention to philosophy, provided that they limit their outlook, regard science as the rational systematisation of certain sensory experiences, and do not attempt to 'bifurcate' their experience into a cognising self and cognised world.[2] Now the use of group-structure, in terms of which the fundamentals of modern physical theory are

[1] Cf. e.g. Eaton, *General Logic*, p. 585 *et seq.*; E. T. Whittaker, 'The new algebras and their significance for physics and philosophy', *Year Book of the Royal Society of Edinburgh*, p. 1 (1943).

[2] A. N. Whitehead, *The Concept of Nature* (1920); *Principles of Natural Knowledge* (1919). Cf. also Chapter IV. So also students of symbolic logic can proceed without asking the philosopher to decide what they mean by propositions, the self, etc., in virtue of the device of logical constructions.

formulated,[1] enables the physicist to avoid this bifurcation, while still keeping the objects of physical science common to different physicists in a way that sense-data are not.[2] If this interpretation is correct, it means that modern physics explicitly adopts a method in virtue of which it can go ahead, as Whitehead showed, without considering the relation of the cognising self to the objects of cognition.

Presumably we have here the explanation of Eddington's insistence on the subjective aspect of cognition as the source of our physical beliefs.[3] If this is so, Eddington's views here are not to be treated as philosophical, but rather as applications of Whitehead's view of the way a scientist may work if he wishes to evade philosophising. In that case there is no real quarrel between Eddington and the realist philosophers, except where Eddington misinterprets his method and draws philosophical conclusions from it.[4] On their own ground each is correct, and Eddington's criticisms of the realists are beside the point.

Eddington's actual data and methods. We may now summarise the data of which Eddington makes use in the theory under consideration. They are: (i) The propositions of symbolic logic, which are hypothetical, concerned only with the valid forms of inference, and *a priori* valid. (ii) The proposition that physical observations are measurements, carried out on inanimate objects; this defines the scope of physics. (iii) The propositions referred to as the modern physical 'methods of interpretation'; these depend ultimately upon inductive support. (iv) The propositions which summarise relativity and quantum theory; these also depend on inductive support.

The way in which these data are used in the calculation of the fundamental constants may be exemplified by Eddington's derivation of the cosmical constant.[5] He begins by defining symbols corresponding to 'existence' and 'relation', by means of which

[1] P.P.S., p. 142–3.
[2] P.P.S., pp. 150, 198. Statements which accord with the view that modern physics adopts implicitly a method based on Whitehead's view will be found in P.P.S. on pp. 49, 50, 148, 150, 185, 186, 198.
[3] Cf. P.P.S., pp. 67, 143, 190, 195, 203, 204.
[4] Cf. Stebbing, *Philosophy and the Physicists*.
[5] P.P.S., Chapter XI.

the operations of the mathematical theory of groups can be brought to bear on certain characteristics of existent entities and related entities. He then introduces the definition of a physical observation, namely that it is a measurement; and notes that, since a measurement consists in comparing (for instance) a length with a standard length, and each length depends upon a spatial relation between two physical entities, any measurement is associated with four physical entities, and consequently with a 'quadruple existence symbol'. No empirical data have yet been used and no numerical results can be deduced so far. But introducing now the fundamental results on relativity and quantisation, one can deduce the forms of the fundamental laws of physics and the values of the constants in them. For the cosmical constant, one finds the upper limit to the number of 'quadruple wave-functions', which turns out to be finite. Any relativistic wave-function embodies both the fundamentals of relativity and quantum theory and the methods of physical interpretation; the *quadruple* wave-function also takes account of the association of measurement with the number 4. Thus all the four types of data summarised above are required for the calculation.

An example of the calculation of the form of a fundamental law of physics is provided by Eddington's derivation of Dirac's equation—the relativistic wave-equation for an electron; and here again it has been claimed that the derivation makes use of the usual physical assumptions, though in a somewhat disguised form which is easily overlooked.[1]

Such a condensed account cannot do justice to the brilliance of Eddington's mathematical methods, but it has sought to bring out the physical significance of a very remarkable physical theory, by placing it in a suitable philosophical setting.[2] For this purpose it has been necessary to isolate the physical theory from the philosophical statements which Eddington apparently believed to be interdependent with it.

[1] Podolsky, *Physical Review*, vol. liii, p. 591 (1938).

[2] Another short account of the scientific part of Eddington's theory, stressing the importance for scientific method, is given by D. Cruikshank in *Science Progress* for October 1947.

THE PHILOSOPHICAL PART OF EDDINGTON'S VIEW

It is worth considering in more detail the philosophical views which Eddington appeared to regard as integral to his theory. If the foregoing interpretation is correct, they are not essential to it; and if the following comments are correct, they are largely false. We will first state them briefly, then discuss them point by point.

(i) Eddington begins by claiming that his results are based solely upon 'scientific epistemology', by which he means a consideration of the knowledge (using the word in a wide sense) obtained by the methods of physical science. (ii) He states that these results are therefore known to us *a priori*. (iii) He adopts an epistemological position which is perhaps best described as pseudo-Kantian, in that whereas Kant held that a man imposes the categories of substance and causality in virtue of the nature of his mind (considered in isolation from its objects), Eddington appears to hold that a physicist imposes the relativity and quantum restrictions on observation because of the limitations of his 'sensory equipment'. (iv) He concludes that the fundamentals of modern physics are 'wholly subjective'. Each of these four points calls for examination.

'Scientific epistemology.' The phrase 'scientific epistemology' suggests a body of philosophical beliefs independent of the results of any particular observations. But such a body of beliefs would seem to consist simply of two propositions: that physical science ignores all the objects of experience except inanimate matter, and that it ignores every aspect of the latter except the measurable. But Eddington's deductions depend also upon data empirically obtained. The various kinds of evidence that he uses have been discussed above, and it seems clear that his conclusions are not deducible without the use of the results of particular observations. That the results lead to very comprehensive theories does not alter the fact that those theories are supported by inductive evidence and have no more exalted status than is implied by this.

By 'scientific epistemology' Eddington evidently means an account of the actual method of physics, for which his work is

important. His evidence has no bearing on epistemology proper —it could be interpreted equally on a realist or idealist theory of knowledge; and his own theory of knowledge does not follow from his scientific work.

'A priori' propositions. Eddington's conclusions, then, depend upon propositions which are believed *a posteriori*, and are not based solely on propositions known *a priori*—that is, propositions known independently of all experience except such as is necessary to render the terms intelligible and the propositions capable of being entertained (if we may neglect, for the moment, Kant's special use of the term).

Eddington's use of the term '*a priori*' is confusing. When he first introduces it he says: 'I think I am using the term "*a priori* knowledge" with the recognised meaning—knowledge which we have of the physical universe prior to actual observation of it.'[1] This is ambiguous, and Eddington seems to interpret it in two senses, which though perhaps consistent on his own epistemological assumptions are not logically equivalent on a realist analysis such as I am attempting. Sometimes, as when he claims that laws established epistemologically 'are compulsory and will be obeyed universally and invariably', he seems to make '*a priori*' mean 'independent of any particular observation'. Elsewhere he abandons ordinary philosophical usage and writes: 'Epistemological or *a priori* knowledge is prior to the carrying out of the observations but not prior to the development of a plan of observation.' But this plan of observation rests upon previous experience, namely (in current physics) the experiments which lead to the relativity and quantum theories. It is formulated *a posteriori*. In consequence, Eddington's usage here of the term '*a priori*' is a very odd one; the propositions to which he refers are not *a priori* in any sense relevant to philosophy.

Later on in the book, Eddington seems to alter the meaning of '*a priori*' and make it characterise propositions about physical method which he regards as known to the mind in virtue of its

[1] P.P.S., p. 24.

own nature and activity, and not in virtue of any characteristic of its objects. (If it were not for the limitation to physics, this would be just the usage which Kant seems to adopt in the later part of the *Analytic* in the *Critique of Pure Reason.*) Thus, Eddington states that in physics uniformities are imposed on the results of observation by the procedure of observation; and that we impose the usual methods of physical interpretation willy-nilly on the observation; that, in fact, the fundamental laws and constants of physics represent the 'mark of the observer's sensory and intellectual equipment', and that they can be discovered *a priori* by scrutinising certain 'engrained frames of thought'.[1]

Confusions about 'a priori'. Thus we have three senses of the term *a priori* in use in the same book. Only one is relevant to Eddington's scientific work; a second is the usual philosophical sense; and a third is analogous to the special sense used by Kant in some passages. Eddington nowhere justifies his transitions from one usage to another, although they are very important for his conclusions. The confusion of the first usage with the second would account for his claiming a better than inductive certainty for his results. The confusion of the first and second usages with the third leads him to suppose that the mind imposes upon its object certain characteristics which depend on the nature of the mind and not at all upon that of the object—whereas in fact these characteristics are formulated in view of the results of numerous experiments and have the same kind of status as any theory which predicts results in agreement with experiment. Incidentally, Eddington is not dealing with the same problem as Kant, and he rightly rejects the Kantian label; Kant, like Eddington, believed in the imposition of characteristics by the mind on the manifold of sense, but he was considering the categories, and not the much less fundamental characteristics dealt with by Eddington.

The alleged subjectivity of physics. It is perhaps because he drifts into using '*a priori*' in this pseudo-Kantian sense that Eddington comes to regard the fundamental laws and constants as 'purely

[1] P.P.S., pp. 116, 134, etc.

subjective'.[1] But we have rejected the pseudo-Kantian view of the fundamentals of physics, as being unsupported and due to a confusion; we may therefore deny also that they are wholly subjective. It is evidently true that in investigating the laws of material nature we are limited both as to our sensory data and as to our mathematical technique and mental equipment, but these limitations do not introduce characteristics due solely to the nature of the mind. The 'frames of thought' are developed with constant reference to the empirical data, and there are no grounds for the belief that they are formally dependent on the nature of the mind alone and independent of its objects.

CONCLUSION

It does not appear, then, that the claim that the fundamentals of physical theory are independent of experiment has been substantiated. If we want physical beliefs we must get them from the data of observation, not from reflection alone. Our exploration of inductive method was not wasted. Induction remains the fundamental method of natural science; metaphysics remains the source of its essential presupposition. This defines in brief the status of natural science as knowledge, upon which depends its place in life.

[1] This appears from the following passage: 'The fundamental laws and constants of physics are wholly subjective . . . for we could not have this kind of *a priori* knowledge of laws governing an objective universe. The subjective laws are a consequence of the conceptual frame of thought into which our observational knowledge is forced by our method of formulating it.'—P.P.S., p. 105; cf. p. 134.

Chapter VII

Metaphysics and Science

THE object of this chapter is to attempt some account of the method of metaphysical investigation; to suggest briefly what sort of topic can be treated, and from what point of view, and how such a method of argument differs from the scientific method. As an example I shall take an investigation which has had immense influence on European philosophy and is still highly relevant to our present problems: the discussion of change and causality by Aristotle. It will emerge that natural science is irrelevant to such a discussion, which is independent of empirical generalisations about the course of phenomena, and proceeds according to a method of its own; a method that is quite different from that of science, because adapted to a different kind of evidence, a different point of view, a different set of questions. This method, it will appear, is none the less rational; its conclusions are a rational account of reality, based on experience, and their reliability is certainly not less than that of scientific statements.

There are several difficulties in attempting such an account. One is that, although science and philosophy are concerned with quite different questions, their terminologies are close enough to cause confusion. For instance, to a scientist the word 'causality' may suggest a law expressing a correlation of variables, but that is not at all what a realist metaphysician means by causality. Another obstacle is the extremely abstract plane of the argument, which appeals to evidence so general and so simple that our minds are dulled to it; we have to think at an unfamiliar level of abstraction. Another is that the evidence for the argument is not fully appreciated unless one has in mind its applications, the complete view of things that it leads to; the evidence for it is to be found largely in the agreement with experience of the whole account of nature and man based upon it. We shall

glance at some of these applications in later chapters and the Appendix.

Let us first consider (in a highly simplified form) the arguments put forward by Aristotle in his philosophy of nature and in his 'first philosophy' or metaphysics.

CHANGE AND CAUSALITY

Our starting-point is thoroughly realistic and empirical. We want an analysis of change. In science we concern ourselves with particular kinds of things undergoing particular kinds of change; now we want to consider changing reality in general. All things, all phenomena, are subject to change of some sort, or at very least are capable of change; a phenomenon itself is a change. What is change, and how is it to be explained? Some philosophers have been so impressed with the unchangeableness of concepts, such as those of geometry, that they have denied the reality of change in general; we remember Zeno's paradoxes, Achilles and the tortoise and so on, which were to show that motion cannot be real. But to refute such a sweeping denial of the fact of change it is enough to reflect that in our own thought we pass from a state of not-knowing to one of knowing; here is at least one instance of change. Others have been so impressed with mutability that they have asserted that there is nothing else, or have tried to analyse change solely in terms of being and privation, being and its negation. But this is not enough; with those two principles you have only succession, not change. To take a simple example, let us consider the change of a block of wood into a statue: certainly the not-statue becomes the statue; but the block of wood is not merely a not-statue, it is something which *can become* a statue. It has its own shape, but it can lose that shape and receive another, the statue shape given it by the sculptor. Thus the not-being is not just not-being, not mere privation; it is not fully described when we have said that it lacks something. It has not yet received the shape of the statue; but it is *capable* of receiving that shape, a capability that belongs to it and not (say) to an ant or a buttercup. It has a real can-be-ness or potentiality. The

analysis, then, leads to the conclusion that what is real is not only what is actual, but that potentialities are also real. The real includes the potential, the perfectible, the matter, as well as the actual, the perfected, the form. In a thing, then, there is a can-be-ness which is receptive of a diversity of actualities, and is constant beneath the succession of actualities.

So far, then, we have reached the distinction of reality as potential and actual, demanded by the fact of change. But we have considered only one example of it, and that an elementary one. The change of a block of wood into a statue is only a superficial sort of change; the wood remains, only the shape is changed. But suppose one thing changes into another thing—food into living tissue, living flesh into corpse? The same principles can be applied, *mutatis mutandis.* If albumen (a being of a certain kind) changes into part of a man (a being of quite a different nature), then albumen must have a potentiality to become part of a man, a potentiality that can be realised. As in the previous example, wood received the form of the statue, so here the foodstuff receives the form of the organised human body. And in general, if a being A changes into a being B, then A must have a potentiality to become B, a can-be-ness with regard to B that is actualised when it becomes B.

We have then the theory that changeable reality must be a union of potentiality and actuality; or (to change the terminology) of 'matter', by which is denoted the receptive and potential element, and 'form', the actualising element. Thus we have two of the principles that we need in order to give an account of change; two of the *causes* of the change, taking the word 'cause' in the wide sense that includes all the elements on which the existence and characteristics of a thing depend. The potential being may be called the material cause, and the new form which it can receive the formal cause. Both these causes are intrinsic to the new thing, the result of the change, the composite of matter and form. But these two causes alone will not effect the change. Potentiality, can-ness, will not by itself effect is-ness; it cannot alone be self-actualising. The change demands also an efficient

cause, an agent, a 'whence of change', as Aristotle so pithily called it, which must itself be actual. For instance, the sculptor is an efficient cause of the statue; it is he who imposes the new form on the wood; he is already actualised in that he has a mental image of the statue he wants to make. And a fourth element in the causal process is the final cause, the actuality that is the result of the process, the finished statue and the purpose that it fulfils.

This account of change, then, directs our attention to those processes in which we know that an agent, which is in actuality in some respect, acts on some being that is in potentiality in that respect, and causes its potentiality to be actualised, causes its capability to be realised. In the example given, the wood has the potentiality of becoming a wooden statue; the sculptor is in actuality as regards that statue, in so far as he knows what he wants to shape; he is an efficient cause of the block of wood's becoming a statue. Another example is the process of learning. Students are potentially able to understand the binomial theorem; their lecturer is in actuality in so far as he understands it; he is an efficient cause of the students' becoming actual in that respect. No doubt the efficient causes of any particular change are many and complex, and the final causes also; usually in stating the cause of a change we mention only the most recent causes and neglect the great background of conditions without which the change would not have occurred. But this does not affect the general account; it merely complicates its application. The theory rests on reflection about the nature of any change whatever, and the general conditions for any change to occur; it is not upset by the discovery of great complexity in the conditions for any particular change.

Another example, in which incidentally the theory is applied to a change that is not (as in the above instances) caused by a conscious human agent, is the growth of an oak tree. What is required in order that there should be an oak flourishing in a given spot? There must have been a seed, with the special characteristics and potentialities of oak seeds; this is the material cause of the oak, or rather one of its material causes, for the soil,

the atmosphere and other conditions are also material causes. The young plant must have followed a definite law of growth, leading to a structure characteristic of an oak rather than of anything else; this is the form or formal cause. Also the acorn from which the oak develops was a product of a parent oak, which is therefore an efficient cause. The new oak is the final cause of the whole process. A biologist would no doubt express the matter differently, but the essentials of the thought would be unaltered.

It is sometimes said that physical science has shown that there are no efficient or final causes. But this is simply a mistake. Physical science excludes efficient and final causes from consideration, not because they do not exist but because they are not relevant from the point of view of physics. One reason for the misunderstanding is that, so long as physics was dominated by mechanics and mechanical models it was customary for physicists to talk in terms of efficient causality; since it has been recognised that this is not the concern of physics, which deals with laws, physicists have sometimes hastily concluded that efficient causes are non-existent. At bottom the mistake lies in supposing that there is no rational point of view distinct from that of physics and no rational method other than that of induction.

Clearly our account of change and causality is applicable to instances of change in which we can be sure that we are concerned with agents acting upon things; to apply it we must be able to identify the agent and distinguish it from the thing it acts upon. Such agents may be human beings, who can cause changes consciously and designedly; or organisms, which cause changes unreflectingly—for instance, birds feeding their young, or salmon spawning, or bees building their cells. I shall avoid referring in this connection to changes within the inanimate world, since as soon as one tries to examine an example in detail it is natural to appeal to physics, and the agent and causal process then disappear, to be replaced by equations or by mechanical analogies; agents and causes cannot readily be identified in inanimate matter by means of the physical account. The present treatment is designed

to take account of human and organic agents, and not merely of the inanimate world which is the subject-matter of physics. The analysis refers to agents, or technically substances, acting as efficient causes in real changes. It does not refer to phenomena regarded from the point of view of science, leading to empirical generalisations; it is not concerned with events following one another according to a rule. The point of view is metaphysical and quite different from that of science, though equally grounded in experience. It is concerned with the ultimate conditions of change, not (like science) with the description and correlation of phenomena. The analysis presupposes, too, a dynamic view of substance; a substance is, on this view, not a mere substratum of change, but something tending towards its natural end or fulfilment, with spontaneous activities bringing about that fulfilment as far as circumstances permit. A man has activities proper to a man, which can make him a better man; a bird has activities and develops according to the nature of such an organism. This is evidently the sort of view we need if we are to take account of intellectual and moral development, of evolution and organic life, and of spontaneous changes in general.

In any such analysis it is best to keep one's imagination fixed on *man* as the example, because we have, so to speak, inside knowledge of human nature, as of no other; we can define it after reflecting on our own operations; it is the nature about whose potentialities and limitations we can be most certain. By my 'nature' I mean that which makes me a man and not a giraffe or a bit of diamond or a logarithm. I come to a knowledge of my nature by reflection on my actions and experience, which leads me to recognise that (i) as to the body I am material, extended, with a certain mass, shape and so on; (ii) I am besides an organism, with properties common to other animal organisms; and (iii) I am able also to think and to desire rationally; to derive abstract ideas from experience, to reason by means of them, to direct my actions in accordance with rational principles; to use language and live in society. If I had not all these characteristics (at least potentially) I should not belong to the human race. They

are essential properties of a human being; and they point to the nature of a human being; he is a rational animal, an instance of the fusion or combination of rationality and animality. This human nature has certain definite potentialities that a man can in principle fulfil; he can tend towards the perfection of a man's nature. For instance, since this nature includes a reasoning and knowing part, we can be sure that the perfection of a human being must be in accordance with his being able to know; thus to perfect myself in the way my nature requires, I ought to follow truth rather than error, and avoid lies and misleading statements. (Human perfection is evidently quite different from that of a non-rational organism which cannot think or reason as a man can.) My nature also sets limits to what I can become; I can become a better man, but I cannot become a number nor a cat nor an infinite mind. It sets limits to what I can do and make. I can 'make' things in a certain sense; people are said to make an apparatus or a picture, or a play, or a poem, or a theory. But this really means that they arrange material, or ideas, or data of some kind, in a new way; they do not create the data, nor do they dictate the laws according to which it can be arranged. I cannot hold in existence anything more solid than a mental image or a memory; I can arrange, but I cannot literally create or be the root cause of existence. I do not want to go deeply into these matters here, but only to indicate the general line of reasoning which shows that at least in the case of a human being we can have accurate knowledge of the nature of something, and therefore about its potentialities and their limits, and can consider them as agents in causing changes.

In this account of change and causality, have we yet reached the ultimate analysis? We have examined some of the conditions for change, assuming that things exist and have some properties to start with. But we have not yet examined the necessary conditions for their very existence. When Aristotle considered the question, he concluded that finite things require, to account for their existence as such, a first cause, a pure actuality unmixed with potentiality, who must be pure thought and utter beatitude.

This first cause (says Aristotle) is not a creator; it merely puts order into material that would otherwise exist as chaos; it is necessary to a world in which there is order, not to the existence of any world at all. This view is superseded by the more penetrating analysis of St. Thomas Aquinas. It was Aquinas who first took the step of applying the distinction of actuality and potentiality to the very existence of finite reality, and not merely to its changes; he investigated the condition not merely of a thing's being what it is, but of its existing at all—the cause of the existence of anything whatever; and found the necessary condition to be the existence of a self-existent being, who is the first cause and ground of the existence of all other beings. This argument is sketched in the Appendix; we allude to it here, since, as we noted in Chapter IV, the existence of such a first cause may be relevant to the problem of induction.

METAPHYSICAL METHOD

We turn now to discuss the method of this kind of investigation and the status of the conclusions reached. In metaphysical thinking we are seeking a coherent account of the widest possible range at the deepest level of rational thought. Metaphysical conclusions must therefore have the following characteristics: (i) they must be logically consistent; their account of reality must be coherent in this sense. (ii) No type of fact or being must be incompatible with them or excluded *a priori* from consideration. (iii) No aspect or general characteristic of things must be excluded, no level of interpretation unexplored, no depth of thinking shirked. These desiderata provide criteria for judging would-be metaphysical systems. For instance, no system could stand if it had no room for the fact of change, or if the only aspect of change considered were the quantitative aspect. A good example of a metaphysic that fails on at least the second and third counts is that of most Marxists; for they exclude from consideration, *a priori* and without due reason, the most important being, the first cause of all things; and their account of other beings, though realist up to a point, is superficial because the economic aspect is regarded as the only

fundamental one.[1] It could be claimed, however, that the kind of view expressed above fulfils the desiderata satisfactorily. It could further be claimed that it lies so close to all our experience as human beings, that to reject it would render all experience unintelligible at the deepest level. The trouble about expressing it is that there is too much evidence and it is too clear, rather than too little and too obscure; we become so accustomed to the evidence, and to disregarding it, that we tend to forget about it altogether.

Such a metaphysic is based just as firmly as science on facts, and constitutes a rational interpretation of them. It is formulated by reason working on experience, just as radically as is science. Clearly, however, there is a difference in the point of view; the whole approach to nature is different. This difference is reflected in a difference of method, which we must examine.

Metaphysical principles, as was said in Chapter V, are the essential supports of our web of beliefs; they are fundamental to, and presupposed in, all our ordered experience; without them we could not have experience as we know it at all. How do we come to formulate these fundamental metaphysical propositions? Our beliefs form a complex pattern, and it is only with difficulty that we can settle which of them are fundamental. What method shall we adopt in trying to discover the essential supports of the web? Deduction will not do the job for us (though we must use it in our reasoning); to reach a true conclusion by deduction presupposes that we already have true premisses, and we are trying not to leave any presuppositions unexamined. Induction, again, though it is one way of reaching beliefs about the world, presupposes, as we have seen, just the kind of fundamental propositions we are at present investigating. The method of metaphysics cannot, then, be that of logic or mathematics or natural science. It is a more abstract one, which we may perhaps characterise as the method of reflection. It is by reflection on experience that we must seek the presuppositions of our ordinary beliefs, of social

[1] Some people argue that if one is not a materialist then one must be an idealist. It should be clear from the last three chapters that this is a complete misconception. The realist position, which I have tried to sketch, avoids both idealism and the apriorism and consequent narrowness of materialism.

life, of art, of science, of moral action, and so formulate the ultimate conditions of being and change.

It may be asked whether enumeration of instances, the fundamental process of induction, has not a place in metaphysical thought. Do metaphysicians generalise from experience in much the same way as scientists? The answer is that enumeration of instances has quite a different function in metaphysical thinking from its function in the inductive method. In inductive generalisation, the instances enumerated are themselves the evidence for the generalisation; thus, I derive the generalisation that arsenic kills rats, not from any insight into the connection between eating arsenic and dying, but because of many consistent observations which constitute the evidence for the empirical law. But in the reflective method, the enumeration of instances merely fixes our attention on a principle that is then seen as their interpretation. An example from ethics may make this clearer. If I say 'I am responsible for my actions', it is not because I have applied the method of inductive generalisation, but because reflection shows that the principle is a condition of all moral life, without which all human law and much else would be unintelligible. A single action, if fully understood, would be enough to establish the principle; multiplication of instances would then add nothing to its certainty. In the same way, metaphysical principles may be approached by examining instances that exemplify them, not because the enumeration of instances provides the evidence, but because it calls attention to the principle.

The method of any investigation, as I have emphasised, is determined by the subject-matter and by the point of view. The subject-matter of metaphysics is evidently the whole of the objects of our experience: all types of being and all their aspects. The point of view is to elucidate the fundamental facts about their natures and relations, so far as this is possible to reason. In contrast with the natural sciences, which are limited to the consideration of certain kinds of beings and to certain aspects of them, metaphysics should survey the general characteristics of all beings in all their aspects. In metaphysics we have to formulate, by

reflection on experience in its fullness, an account of the fundamental conditions of change, existence and the rest, that shall be logically self-consistent and shall offer an interpretation of the widest range of experience and the deepest insight into it. We need the widest possible range and diversity of evidence. The knowledge of the scientist, mathematician, artist, craftsman, housewife, doctor, lawyer, statesman, priest—all are food for thought for the metaphysician. He needs analytical thought to discover exactly what are the ultimate presuppositions of the beliefs that are taken for granted in ordinary human pursuits, and what are the ultimate conditions for the changes they deal with and for the existence of the beings they concern. He needs balanced synthetic thought to formulate the essential characteristics of the widest range of beings. To test a metaphysical system he must deduce all the consequences that he can compare with experience, and search for confirmation or invalidation. (For example, if a given account of change led to the conclusion that the outcome of all change was arbitrary and unconnected with the cause, we should find on reflection that this was inconsistent with experience about the generation of plants, animals and men, and therefore to be rejected.) Thus analysis, synthesis and deduction are all concerned; and there is constant reference to experience. It is little wonder that the construction of a metaphysical system is more than one life's work, and that tradition is so important in philosophy. Thus Aristotle could survey and synthesise the insights of his predecessors in Greek philosophy; St. Thomas Aquinas could press Aristotle, Plato and Augustine into service. Philosophy is a commentary on life, and it may take several generations to complete the comparison of a philosophy with experience.

SCIENCE AND METAPHYSICS

Metaphysical argument, then, evidently has certain traits in common with natural science. Both are based on experience, and the facts of nature are their common property. Each is concerned with giving a rational account of experience; each, therefore, uses logical consistency and agreement with fact as

criteria. Each in its own way essays an explanation of facts, an interpretation, and each uses experience to test its statements. Yet it is evident that they are different in kind. The point of view of metaphysics is more fundamental; it cuts deeper and seeks to reveal the ultimate conditions for the existence of anything. The outlook of science, is, so to say, horizontal; its explanations are concerned with the relation of natural phenomena to each other, not to man (who can control them), nor to the first cause (who initiated and upholds them); its explanations are concerned with bringing a phenomenon under a law, or a law under a theory. The outlook of metaphysics, however, is also vertical; it can survey the relations of beings at various levels to each other; its explanations are concerned with identifying the causes of things. It does not explain the behaviour of things by stating the laws of that behaviour, but inquires into the causes both of the thing and of the laws. (This is why it could fill in the gap, the presupposition that the theory of induction brought to light.) Accordingly it appeals not to individual observations, nor to empirical laws of nature, but to wider surveys of experience. It is not based on induction, but on reflection. It is more general, more abstract, more rigorous. What it lacks in detail it makes up in breadth and depth.

Natural science and metaphysics, then, are not to be distinguished in terms of some facile distinction between objective and subjective, or between verifiable and unverifiable, or between reason and emotion. Both use the method of reason working on experience; both require subject as well as object, thought as well as data; both appeal to the correspondence between their propositions and the facts they refer to. Again, the difference is not that science uses observation, and metaphysics deduction; nor that metaphysics is sterile and science progressive. Both, on the contrary, use o[illegible]t in different ways; the one as material for induction, the other as material for reflection. And both use deduction, and for the same purposes: to find the consequences of an hypothesis, for comparison with the facts and to check the internal consistency of a system. We cannot build up

an antithesis between science as an affair of demonstration, based on observation, and metaphysics as an affair of mysterious word-spinning immersed in idle speculation, facile invention and irrational credulity. The whole picture is false. Clarity of thought is a speciality of philosophers, even more than of scientists; their appeal, too, is to observed facts, though these are not studied inductively but reflectively; metaphysical argument is tied to experience just as closely as is science, but at a different level.

In a sense, metaphysics and science are complementary. Metaphysics does not deal with the detailed behaviour of nature, science does not deal with the ultimate interpretation of natural knowledge. They are both necessary to a synthetic view of the world. But the relation is one-sided; science cannot begin without assuming a metaphysical principle, whereas metaphysics does not presuppose any scientific principle for the validity of its conclusions. One of the functions of metaphysics is to examine the grounds for the presuppositions of science, just as one function of logic is to lay bare these presuppositions. But this does not exhaust metaphysics; the world-picture of Aquinas, for instance, was not conceived merely to supply a foundation for science; his great synthesis about the first cause, creation, change, man as rational and immortal, happiness and the rest, is far wider than the scope of science. It is philosophy, not science, that deals (so far as reason can) not only with the fundamental truths about nature, but with the matters of greatest importance to man.

CONCLUSION

It appears, then, that besides the inductive method of science there is another way of gaining knowledge: the method of reflection on the general principles that are needed if experience is to be intelligible. These metaphysical conclusions are based on the rational interpretation of experience, just as are those of natural science; the differences are due to the difference of subject-matter and point of view, reflected in the difference of method. It is this sort of approach that we need to suggest grounds for believing that the major presupposition of the inductive method is true.

PART THREE

Applications

CHAPTER VIII

Beauty and Science

So far we have been thinking of science mainly as an approach to truth. We have not yet mentioned goodness or beauty. In this chapter and the next we shall explore their place in scientific life.

At first sight, it might seem that science cannot exhibit beauty. Does it not exclude the forms and qualities that delight us, reducing all to a mathematical uniformity, refusing to have anything to do with the wonders that we see in sunsets, in apple blossom, in mountains, in music?

> . . . Do not all charms fly
> At the mere touch of cold philosophy?
> There was an awful rainbow once in heaven:
> We know her woof, her texture; she is given
> In the dull catalogue of common things.
> Philosophy will clip an angel's wings,
> Conquer all mysteries by rule and line,
> Empty the haunted air, and gnomed mine,
> Unweave a rainbow. . . .

But we should conceive beauty too narrowly if we restricted it to what is apparent to the senses. (Perhaps after all this is what Keats meant.) We ought to admit also intellectual beauty, the appreciation of form and harmony in things of the mind:

> How charming is divine Philosophy!
> Not harsh and crabbed as dull fools suppose
> But musical as is Apollo's lute.

BEAUTY AND FORM

How can we define beauty in a general way that includes the beauty of mathematics, of science, of philosophy, as well as of character and of visible tangible forms? How is beauty related to goodness and truth? The discussion of these 'transcendentals' and their relations is difficult, but at least we can say that truth

is obviously connected with knowing, with intellect, and goodness with loving, with intellectual desire. We have considered truth so far only in connection with true propositions; here we must consider a wider sense, in which anything is said to be true in so far as it is knowable; likewise by the 'goodness' of anything we mean its lovableness. Beauty in our general sense is closely connected with these two, and perhaps we may say that anything (a tree, a person, a theorem, a poem) is beautiful in so far as its truth and goodness lay it open to our minds, so that we can grasp its form intuitively. A friend is beautiful to us—more beautiful than, say, a stone—because we have a certain knowledge of his character, and rejoice in it. We know him as a unity, a person—not exhaustively, but yet not merely as a series of episodes or aspects or appearances. And we know him, not merely by discursive reasoning—comparing, contrasting, discussing, abstracting—but also by some measure of intuition, sympathy, *Einfuhlung*, assimilation, insight. For instance, we do not argue that on certain occasions in the past he has been found reliable and so there is a certain likelihood that he will not let us down to-morrow; we simply trust him, on the ground that we know his character. It is this intuitive knowledge of a lovable being that constitutes the perception of beauty. It is not an affair of the senses and emotions only, but of insight and love as well. I do not deny that emotion plays a part in the experience of beauty, but suggest that it is secondary; it is the intuition that is primary and is the root cause of the joy. Nor do I deny the contribution of purely sensuous delight, but hold that though itself good it is relatively unimportant except in relation to the vision it serves. Beauty, then, is one kind of good, arising from one kind of knowledge; it is intimately connected with goodness and truth.

It follows that beauty depends on form—unity, order, pattern, design. For a thing is both more knowable and more lovable the more developed is its form. A friend is more beautiful than a kitten, a kitten more than a pebble. Beauty increases as we go up the scale of existence—inanimate, animate, human. Now it is in respect of form that these levels of existence differ from one

another. The material is the same for all—the same set of chemical elements, the same set of physical laws; but the forms are different. The form of the man is a rational soul and so higher than that of the organism, which in turn is capable of spontaneous growth, development and reproduction and so is higher than that of inanimate nature. And the higher form is at once more knowable and more lovable; and since it is more open to our minds, and since when intuited it gives us the more delight, it is also more beautiful. It is by degrees of form, then, that we can assess beauty.

BEAUTY IN ART AND LITERATURE

We may inquire first what account can be given on these principles of beauty in painting, in sculpture, in poetry. These arts, I shall assume, are concerned with *significant* forms. The form of a work of art is distilled from the artist's experience in order to convey an intuitive vision of some reality; some person, situation, mood or occasion. The 'outer' form of the work and the 'inner' form of what is represented are both important. What delights us at first sight in a painting is the intuitive knowledge of its outer form. The prima facie beauty of a painting is not the beauty of what it represents; it has an independent beauty, related to the joy of seeing something as a whole, of reaching intuitive knowledge; the mind rejoices in the free movement of the intuition, in the relief from ratiocination. The artist has solved a problem in line, colour and composition; he has not merely copied, he has selected, emphasised, concentrated; he has made something that is visibly a unity, and a delightful unity. If now the outer form is significant of a beloved reality, we are the more delighted, because of the further beauty that we touch through the work of art—the inner form revealed by means of the outer form; for instance, the character revealed by a portrait. We find a portrait beautiful because in it we see, condensed into one form, the whole complex of a character, a human life. If the character is beloved, too, we are the more delighted with this fresh beauty revealed and intuited through art. Raphael's

Madonna in the Meadow is a superb piece of painting, and it would still be magnificent if we knew nothing of the people represented in it. But since we do know the tender relation of son and mother, the sight of the picture conveys far more than a lovely whole of colour; it gives a vision in the mind's eye of something that we love and delight in contemplating.

> O! how much more doth beauty beauteous seem
> By that sweet ornament which truth doth give!

Again, if we go to a performance of Shakespeare's *Henry the Fifth* we see, unrolled before our intuition rather than our reason, the epitome of a vast variety of human life, brought into unity by plot and characters, so that we cannot but admire the play as a play. And in so far as the reality represented is itself beautiful, we are the more delighted; whether we merely enjoy the vigorous Elizabethan world-picture that the play exhibits, or whether we admire besides the truth of its valuations of honour, courage, kingship and so on.

A work of art, then—a significant form—opens to us both its own beauty and that of the reality it represents; the outer form is significant of the inner form. Evidently the work of art will be the greater, the greater the range and depth of the experience drawn upon. We all think the *Divine Comedy* a greater poem than some slight lyric that may nevertheless be as adequate technically to its tiny theme as Dante's poem is to his mighty one. The poem (or the portrait, or the sculpture) is the greater, moreover, the more the outer form is adequate to the reality represented. It should be transparent, should reveal to our intuition the form of the reality that it expresses. Compare the familiar doggerel:

> Twinkle twinkle, little star,
> How I wonder what you are!
> Up above the world so high
> Like a diamond in the sky,

with a passage from Shelley's *Prometheus Unbound*:

> . . . The point of one white star is quivering still
> Deep in the orange light of widening morn

Beyond the purple mountains: through a chasm
Of wind-divided mist the darker lake
Reflects it: now it wanes: it gleams again
As the waves fade, and as the burning threads
Of woven cloud unravel in pale air . . .

Each passage is inspired by the sight of a star, but while the second brings a superb scene vividly before us, the first makes even the night sky seem trivial.

Further, in proportion to the reality represented, the outer form must have a unified complexity, an ordered richness, a variety in unity. The power of Shakespeare's sonnets, or of 'metaphysical' poetry, for example, is surely due to the great range of experience concentrated into one of those vivid poems, allied with the corresponding wealth of phrase and with the close-knit structure. The richer the diversity, and the closer the unification, the more do we find beauty in such a work. Here, for instance, in Shakespeare's Sonnet XIX, is unity in diversity exemplified in an amalgam of nature, mythology and human love, mutability and immortality, supplication and defiance:

Devouring Time, blunt thou the lion's paws,
And make the earth devour her own sweet brood;
Pluck the keen teeth from the fierce tiger's jaws,
And burn the long-liv'd phoenix in her blood;
Make glad and sorry seasons as thou fleets,
And do whate'er thou wilt, swift-footed Time,
To the wide world and all her fading sweets;
But I forbid thee one most heinous crime:
O! carve not with thy hours my love's fair brow,
Nor draw no lines there with thine antique pen;
Him in thy course untainted do allow
For beauty's pattern to succeeding men.
  Yet do thy worst, old Time: despite thy wrong;
  My love shall in my verse ever live young.

And here is a poem of George Herbert's which perhaps is even more successful, because the appeal to sense, imagination and memory is as vivid, the form at least as balanced and compact, and the thought more realist, feeding the mind as well as the fancy:

Sweet day, so cool, so calm, so bright—
  The bridal of the earth and sky;
The dew shall weep thy fall to-night
  For thou must die.

Sweet rose, whose hue angry and brave
  Bids the rash gazer wipe his eye,
Thy root is ever in its grave
  And thou must die.

Sweet spring, full of sweet days and roses,
  A box where sweets compacted lie,
My music shows ye have your closes
  And all must die.

Only a sweet and virtuous soul,
  Like seasoned timber, never gives;
But though the whole world turn to coal,
  Then chiefly lives.

Now I do not say that unity in diversity is the whole of beauty; but it is the element common to beauty in art and literature and to beauty in intellectual pursuits. It gives us the clue to beauty in philosophy and mathematics, and it is the characteristic by which we can best assess it. Mathematics lends us a simple example. A table of integrals is less beautiful than an elegant mathematical theorem, because our minds can seize the theorem as a whole, but not the collections of integrals, which has no logical unity. A system of such theorems subsumed under some general principle, or still more an ordered treatment of a whole branch of the subject (such as the integral calculus), has a still fuller beauty, because of its richer variety-in-unity. In philosophy, again, we may find a beauty in great metaphysics that is lacking in the work of one who confines himself to mathematical logic.

The key, then, is variety-in-unity in the human construction, agreeing with the form of what it represents. Accordingly we can assess intellectual beauty in terms of form, and form in terms of unified variety.

BEAUTY IN SCIENCE

We can now turn to natural science and to material nature which is the source of its data. Each has its distinct beauty. We

may think of science as analogous to a work of art, indeed as itself a work of art, an artefact. It has its own form, with a unity of its own, constructed, as we saw in Chapter III, to be significant of the form of nature. It is not, however, a complete account of nature, as we have seen; it leaves out important aspects of nature and it ignores the relations of nature to the first cause and to man. The beauty of science, then, is not the same as the beauty of nature; they differ somewhat as the beauty of a portrait differs from the beauty of the character represented. We can treat first of science as an autonomous scheme,[1] omitting for the moment its relation to nature. In what follows I shall write of physical science, but I imagine that a parallel account could be given for biological and psychological sciences.

Physical science has a unity of its own; it is a systematisation of sense-data, a mathematical unification of measured quantities. Measurements are brought into relation with one another by constructing functional relations from them, and these empirical laws are related by being subsumed under more general laws. These laws, again, are unified by theoretical interpretation from which (if it were complete) the empirical laws could all be deduced, and thence the behaviour of experimental systems. For instance, our observations on air led to an empirical law, which is a particular case of the general gas laws, which are deducible from the kinetic theory of gases. The kinetic theory of gases, again, depends on the general principles of Newtonian mechanics, which in turn is a particular case of the more general mechanics that includes quantum theory and relativity. Thus in the unity of physical science are combined measurements of diverse phenomena, empirical laws for them, and theoretical interpretations of many degrees of generality. All are unified in so far as they are deducible as particular cases from the general theoretical interpretations.

It is in this unity, this form, that we can find the beauty of science. This is the kind of harmony, of variety-in-unity, that characterises it and determines its version of beauty. It is not the

[1] Cf. Chapter IV, p. 51; Chapter VI, p. 98.

same as the beauty of pure mathematics. The unity of mathematics is due simply to logical rigour; it is the unity of propositions validly inferred from one another without regard to their agreement with fact. But the unity of science is not solely due to the logical rigour of theoretical interpretation; it includes also the experimental observations, which are unified with the logical scheme, in so far as deductions from that scheme are in agreement with them. A 'beautiful piece of work' in science is one that is in its way complete and rounded, one in which the facts all exemplify some generalisation or theory. The unity of science is perhaps less perfectly accomplished than that of mathematics, but it is a richer unity in so far as it includes a further type of harmony, between a set of logically connected propositions and an independent set of observed data. Not only is the kinetic theory a logical whole and logically related to more general theorems, but deductions from it agree with the facts of observation. In the theoretical schemes the order, like that of mathematics, is due to deducibility; but taking science as a whole, its order includes also the agreement between observations and theory. This is the version of variety-in-unity peculiar to science, the source of the beauty that scientists find in it. And the more complete and integrated the theoretical account, the more diverse the phenomena related by it, the greater will be the beauty of science as an autonomous whole.

If we compare this version of variety-in-unity with that of metaphysics, we must admit that both the variety and the unity are inferior in science. The range of facts that science deals with is restricted, and, as we saw in the last chapter, the explanations are, so to speak, horizontal, internal to nature, explaining one part of nature by another. The universality of metaphysics is missing, and so are its 'vertical' explanations, its account of the relations of nature to man and the first cause. Yet the beauty of science appeals to us as solid and reliable; it keeps close to earth; it is not the less fascinating for being limited.

The comparison with literature is more complex. First, the beauty of literature is not purely intellectual; it appeals to the

intellect through the senses and passions. It works on us with the sensuous beauty not only of its own sound, rhythm and structure, but also of the experiences that it recalls. It presents ideas vividly and concretely to the imagination. In consequence it is capable of moving mankind in general more easily than either science or philosophy; its beauty is certainly more potent than theirs in this sense. Secondly, literature can draw upon the resources both of science and philosophy—the detailed picture of the one, the universal interests and fundamental explanations of the other. That science can thus contribute to the beauty of imaginative literature is shown by poets as far apart as John Donne, who constantly presses into service the natural knowledge of his day; Shelley, on whose scientific imagery Whitehead has commented:[1] Francis Thompson, some of whose poems and essays are saturated with physico-chemical images; and Robert Bridges, whose *Testament of Beauty* contains memorable passages on science. And we have besides the explicit testimony of a contemporary poet:[2]

> I saw sweet Poetry turn troubled eyes
> On shaggy Science nosing on the grass,
> For by that way poor Poetry must pass
> On her long pilgrimage to paradise.
> He snuffled, grunted, squealed; perplexed by flies,
> Parched, weatherworn, and near of sight, alas,
> From peering close where very little was
> In dens secluded from the open skies.
>
> But Poetry in bravery went down,
> And called his name, soft, clear, and fearlessly;
> Stooped low, and stroked his muzzle overgrown;
> Refreshed his drought with dew; wiped pure and free
> His eyes: and lo! laughed loud for joy to see
> In those grey deeps the azure of her own.

SCIENCE AND NATURE

So far we have considered science merely as a unified scheme. But we must also regard it as a source of rational beliefs about

[1] *Science and the Modern World*, p. 104–7.
[2] Mr. Walter de la Mare.

material nature. Since it exhibits a logical order, and since it is based on examination of nature, science evidently presents to us some image of the order in nature, the form of nature; of the harmony, the causal interdependence of events. But, as we saw in Chapter III, it appears that in physical science we symbolise cause-effect relations by mathematical equations, which are purely logical relations. The wave-equation for the hydrogen atom, for example, substitutes implication for causation; the causal order that regulates the behaviour of hydrogen is symbolised by the mathematical order that relates the variables in the equation. Thus the physical scheme cannot be a full account of nature; none the less it is a genuine account from a certain point of view. Science is significant of nature, its order symbolising the order of nature.

We have seen, moreover, how the very method of physical science dictates that it must be content with thus reflecting rather than adequately describing, the form of nature. The twofold restriction, to inorganic nature and to its measurable aspects, entails that the theoretical scheme shall be mathematical and therefore use logical relations to symbolise the causal relations of nature.

Physical science, then, is not an adequate description of nature; it is a portrait made by an observer with a particular point of view and a definite limitation on his vision. He selects the data, somewhat as an artist selects. Science is a construction, made by synthetising selected data; it is not an untouched vision of nature. Certainly it gives us some understanding of the order in nature's workings, but not a full understanding. Moreover, it entirely neglects the relation of nature to man and to the first cause. From natural science we cannot learn what material nature is for, how and why it exists at all, and why it has any laws. In so far as we can answer these questions we do it in terms of a wider survey, made explicit in philosophy and theology, expressed concretely in poetry, felt vividly in the nature-ecstasies of a few. The beauty of nature, then, in its widest sense, is not to be apprehended through science alone. We need something like the

outlook of which Dr. Sherwood Taylor writes: 'The man of science who wishes to make his expert knowledge contributory to an absolute wisdom must first complete it by making it a full knowledge of nature, not in all her details, but in all her aspects. . . . Man can achieve four modes of apprehension of nature, of which the scientific is but one. First is a mere perception of her surface; diversity without unity. From these man rises through successive stages of integration, first, to the perception of the beautiful in nature and its integration in art; next, to the apprehension of the order of nature through science and philosophy, and the discovery therein of harmony; and, lastly, the apprehension of the world as made one in its orientation to God.'[1] I would myself prefer to say that besides the minute investigations of science and the unification of them that theoretical science effects, we need to understand the relation of nature to man and God, through philosophical and theological wisdom and through the intuitive vision expressed in art. The upshot is the same: we need a wisdom that transcends science if we are to have a full view of nature. Science alone will not give us the conceptions we need for a full knowledge of nature and its setting; it is one element in the synthesis, but without the others the scene would be impoverished indeed.

CONCLUSION

Science, then, if the foregoing account of intellectual beauty is admissible, has a beauty of its own, peculiar to itself, characterised by the type of variety-in-unity that it exhibits. It plays a part, too, in revealing to us the beauty of nature, though we shall miss much if we do not supplement it with other modes of knowledge. It is noteworthy that this account of beauty in science depends upon the preceding account of the method of science, and not upon particular conclusions of science, which illustrate it rather than support it; the fertility of the general approach by examining scientific method is once more evident.

[1] *The Fourfold Vision*, Chapter VI.

Chapter IX

Ethics and Science

SCIENCE AND THE GOOD LIFE

CAN science contribute to the good life for man? Has it any contribution to make to human welfare, or is it a mere selfish game, an excuse for enjoyable tinkering, a fiddling while our fellow-men are oppressed and starving? In this chapter we shall consider its place in the personal life of a scientist; in the next its role in society at large.

This separation of personal and social ethics is to some extent arbitrary; for a man's welfare lies within a community, he is a social animal by nature, and there is no sharp division between ethics and politics in the wide sense. The view of man and society that I shall adopt is neither the extreme of individualism, according to which a person has no duties to society, nor the extreme of collectivism, according to which a person exists solely for the collectivity; by contrast with both, I hold that a person forms part of a larger whole and ought to contribute to the good of the whole, but also that a person has rights which society cannot abrogate, and under this aspect he is not for the society but the society is for him. Ethical problems are thus to some extent separable into two groups, one concerning the person as such and the other society as such; though treatments of the two fields, such as this chapter and the next, are necessarily interlocked.

Science and wisdom. We saw in the last chapter that science has a beauty of its own and also opens for us a new window on the beauty of nature. Thus through science we can survey new truths and new aspects of beauty. And this should lead to a better appreciation of values in other fields; with a wider range of examples before us, we ought to be able to widen and deepen our comprehension of truth and beauty in general. More specifically, however, science contributes to our knowledge of nature.

Now a knowledge of nature is part of wisdom, and we need it to live properly. If we are to live rationally, if we are to guide ourselves wisely by right means towards good ends, we must understand our situation. We must therefore have some knowledge of nature, of mankind, and of God; and natural science evidently contributes much to our knowledge of nature and something to our knowledge of man. Science, then, can help to make a man wise; it is a worthy part of the pattern of a good life. It is not itself wisdom, but it can contribute to wisdom: science and wisdom should not be wholly unconnected in a scientist's life. Science is, therefore, good 'in itself', if by that we mean that it can contribute directly to personal virtue and wisdom; it is not just a means to welfare, but part of welfare itself.

Science as a version of rational life. But science is always developing, always in growth and change. Scientists contribute to, or at any rate follow, this continual evolution. Scientific life—the life of research or teaching in science—has its values, which are only partly determined by the values of the finished scientific knowledge; the process of winning that knowledge is also of value.

The key to these values is that scientific life is a version of rational life, a special adaptation of certain principles common to all rational life. Scientific life is a version of life lived according to right reason. First, it demands the experience of the senses; not haphazard experience and hearsay evidence, but careful observation and intelligent searching; a mind alert for novelty but trained also in cautious verification. Second, it demands that observations shall be interpreted by reason, which brings order into the data of sense; it requires rigorous logic, controlled imagination, intellectual insight, clear analysis and wide synthesis. It requires that we learn about nature from experience (as distinct from spinning myths) and that we interpret that experience by reason (as distinct from merely remembering or applying it). Third, it is characterised by a continual interplay of experiment and theory; experiments suggest hypotheses, hypotheses in turn suggest experiments which may verify them. Scientific life, then, requires a rational unity of thought and action. Fourth, it is a

developing tradition: neither a code of unalterable rules, nor, on the other hand, a formless collection of varying authenticity, devoid of established criteria for judging new developments. The scientific spirit will tolerate neither a sterile immobility nor a rootless fickleness: scientific beliefs need periodic overhaul and constant adjustment. Fifth, as a consequence, scientific life requires freedom: freedom of thought, of discussion, of publication, and of investigation. Sixth, scientific work is a social as well as a personal enterprise. All scientists must take on trust a vast body of facts established by their colleagues and predecessors, and it seldom happens that any important field of scientific investigation is monopolised for long by one man. Consequently, the practice of science requires both personal integrity and respect for one's colleagues; tolerance for others' opinions and determination to improve one's own; and care not to overstate one's case nor to underrate that of others. Thus a mental 'climate' is favoured which is a balance of appreciation and criticism.

All the general principles named belong also to other studies, and indeed to any rationally conducted enterprise, from philosophical research to farming. Every student can recognise in them the principles of his own speciality. But in pursuing natural science we use a special adaptation of those principles, a particular version of rational method. Each element is given a special character by the special method and subject-matter of science: by its limitations and by its close contact with matter. Historians use another version, philosophers yet another; craftsmen, business men, housewives, all have their own special rational habits adapted to the work in hand. The method of natural science is not the sole and universal rational way of reaching truth; it is one version of rational method, adapted to a particular set of truths.

Science as a microcosm of rational life. Must science then remain not merely distinct but separated from the more human side of life? How can it be integrated with other studies and with the rest of a scientist's life? The key to this integration is that scientific life is not only a version, but a *microcosm* of rational life. Scientific work is rational life in little. By studying science and becoming

familiar with that form of rational activity, one is helped to understand rational procedure in general; it becomes easier to grasp the principles of all rational life through practice of one form of it, and so to adapt those principles to other studies and to life in general. Scientific work, in short, should be a school of rational life. Reason interpreting experience uses many different methods, depending on the subject-matter and the point of view, but they all throw light on one another. Science, then, is not to be confused with other modes of thought, but neither is it to be entirely divorced from them. Properly used, it should be a school of rational method.

We shall go astray, however, if we suppose that scientific method is the whole of rational method, and try to apply it where it is inappropriate. We have seen the insufficiency of science in several fields, and there are more examples to come. In general we may say that natural science gives us a certain training that is useful to some extent in dealing with the concepts of metaphysics, morals, politics and aesthetics, but does not give us those concepts themselves. It teaches us to be faithful to facts, but does not familiarise us with (for example) the facts about duty, choice and happiness that we need in studying morals, nor with the facts about justice, authority and law that we need in studying politics. These conceptions, and many others, we derive from reflection upon the relevant data in human life; not from induction.

Science and asceticism. It is not only the intellect that can be developed by scientific life, but the will as well. Science imposes a discipline that can leave as strong a mark on the character as can its stimulation of the intellect. All who have been engaged in scientific research know the need for patience and buoyancy and good humour; science, like all intellectual work, demands (to quote von Hügel) 'courage, patience, perseverance, candour, simplicity, self-oblivion, continuous generosity towards others, willing correction of even one's most cherished views'. Again, like all learning, science demands a twofold attention, to hard facts and to the synthetic interpretation of them; and so it forbids a man to sink into himself and his selfish claims, and shifts the

centre of interest from within himself to outside. But for scientists there is a special and peculiar discipline. Matter is perverse and it is difficult to make it behave as one wants; the technique of experimental investigation is a hard and chastening battle. Experimental findings, too, are often unexpected and compel radical revision of theories hitherto respectable. It is in this contact with 'brute fact and iron law' that von Hügel found the basis of a modern and scientific asceticism, and in submission to this discipline that he found the detaching, de-subjectifying force that he believed so necessary to the good life. The constant friction and effort, the submission to the brute facts and iron laws of nature, can give rise to that humility and selflessness and detachment which ought to mark out the scientist.

Science in practice. I suppose that when a man has a 'bent' towards science the reason is that his temperament and abilities fall in with this particular version of rational life. He enjoys the solidity of the data of science—facts as firmly established as facts can be; the balance of fact and theory, the ease with which they are cross-checked, the freedom to take up one or the other as abilities or mood suggest. He admires the unending novelty of interpretation, against the firm background of fact; the balance of change and stability, of settled presuppositions and new movements breaking their bonds, analogous perhaps to classical and romantic elements in literature. He likes the blend of freedom to put forward new evidence and any theory it will bear, with constraint due to the authority of old and proved results. He enjoys the balance of manual and intellectual work. He likes both the discipline and the simple joys of science, even apart from its rewards in the form of knowledge. If he is that rare being, a master scientist, he enjoys the balance of intuition or imagination with hard reasoning in making creative advances.

Science, then, can help to stimulate the intellect and discipline the will; it can help to form a full mind and a firm character. To this extent it has bearings on the good life. But it cannot do so by itself: only if it takes its proper place in a liberal outlook, an open culture. The right use of science as a school of rational life

depends upon its being set in a matrix of other studies and other activities. Otherwise its full value will not be realised and it will be in large part unfruitful.

SCIENCE AND MORAL PRINCIPLES

So far in this chapter we have taken for granted certain ethical principles; in particular, that the good life is lived according to reason, that it needs both wisdom and discipline, and that it is both personal and social. We have assumed also that these principles are independent of science. But in recent years it has sometimes been asked whether ethics has any rational basis other than science; whether we could extend scientific method to morals and so build up a new ethic. Before we consider such questions, we must give some indication of the problems of moral philosophy and of the kind of way in which they can be approached in accordance with realist principles.

The tradition of moral philosophy. First of all, moral philosophy considers a man as a responsible agent, as a cause of his own acts. Suppose a moralist is asked to give his opinion of Hamlet's killing Polonius. The first question is, Was Hamlet in his right mind at the time—was he master of his actions? If he was not—if he was crazed, if the act was the mere effect of subconscious processes—the moralist is not concerned; for he deals only with fully human acts, which are guided by reason. Supposing the act to be deliberate, the moralist must consider three things: was Hamlet's motive a sound one, was the act in itself a right one, and were the likely results in themselves good? Concerning the rightness of the act, he would have to say whether killing is legitimate in any circumstances, and whether in the circumstances of Polonius' death it was murder or not. For an action is only fully justified if the intention is good, the act itself right both in general and in the particular circumstances, and the likely results good.

Moral philosophy proper, however, though it exists for our guidance in practical affairs, is not as such concerned with the application of principles to particular occasions, but with the

elucidation of the principles themselves: the analysis of the characteristics of the good life and of right action, the precise treatment of what we vaguely refer to when we talk of duty, right, good, happiness and other moral notions. We must now see how such notions are grounded in reality and how we come by them. Only the briefest outline can be given; for fuller treatments the reader is referred to the Bibliography.

We have argued that man has a certain definite nature, with definite potentialities; he is rational, capable of knowing truths and desiring goods, and of acting accordingly; he is also an animal, equipped with animal instincts; and he is a social being, not an isolated individual; thus his potentialities are those of such an animal, rational, social nature. Now, in ethics as in metaphysics, we may find a key in considering the actualising of potentialities. Here the actualising is conscious and self-directed. If a man is to live and develop in accordance with this nature—if he is to seek the full development of a being who is at once animal and rational, personal and social—his life and actions must show a certain pattern. Truthfulness and wisdom are ends befitting a being equipped with intellect; love and self-discipline become a being equipped with a rational appetite for the good; justice, honesty, faithfulness, altruism and mutual love are fitting in human beings because they are also social by nature. Conversely, lying, hate, greed and cruelty are inimical to the ends implicit in human nature; they are opposed to the directions of development which that nature lays open for mankind. The good life is concerned with pursuing ends consonant with our nature; with realising, fulfilling, what we are made for; this determines the moral qualities that men and society should aim at, and so gives us the guiding principles for action both on the individual and social planes.

This presupposes that we have a clear notion of the nature of man and of his ends. But experience shows that such notions are obscure and hard to clarify; and if they were all we could rely on, the good life would be difficult indeed for those who have not been brought up in a well-defined tradition. There is, however,

another element in moral conduct; namely our ability to recognise duties, to understand the word 'ought', to decide that a certain action here and now is a right action. I do not need to construct a complete theory of man before I can recognise that I ought not to kill the child next door to be rid of its crying, that I ought not to accuse falsely a friend in order to cover up some ineptitude of my own, that I ought not to spread lies to bolster up my reputation. I could know that I ought not to act thus, and that I ought to act in other ways, even though my notion of human nature and its ends were hazily imprecise. In the order of discovery, it seems, the recognition of duties, of moral imperatives, precedes any coherent view of the ends of human life. And it is precisely the experience of moral obligations, and the resulting consideration of right conduct in various circumstances, that enables a man to clarify his ideas about his ends and his nature. It is the recognition of duties, the development of habits of right action, the increasing insight into the meaning of 'I ought', which supplies the data for reaching conclusions on the notion of good and on the ends of human life. It is only by reflection on experiences of this kind—right actions freely done—that the concepts of moral philosophy can be reached at all. As we reflect, our understanding both of duties and of ends, of right and of good, extends and deepens. Our conduct on a given occasion may ultimately be based either on the principle of seeking the good and doing those actions which seem to be means to it; or on the principle of doing what we know we ought, which will certainly lead towards the good. (To act from duty, and to act with a view to progress towards the ends of life, are not incompatible; as an example we have only to reflect upon the pursuit of knowledge, which may be a duty and which can also make a man wise.) The two approaches complement each other: the pursuit of the good is an inadequate guide, because our notion of the good is at first too vague, and we may fall into egocentric ways; on the other hand, to rely on recognition of duties alone is unsatisfactory, because it gives us no criterion for deciding between two opinions or between two incompatible actions which prima facie are both duties; a

combined use of the two complementary principles may be needed.

The data required before we can reflect on moral concepts is obtained by experience of the realities of moral life in practice: of duties to friends, children, benefactors; of attempts at courage in disappointment and danger; of efforts at generosity, service and love; of discrimination of ends, and choice of means. Once the relevant data have begun to accumulate, we can begin to formulate our notions of the main ends of man, of the ultimate good at which he should aim. When through experience we have realised the meanings of moral distinctions, such as those between egoism and altruism, duty and self-interest, happiness and pleasure, we shall not be in danger of identifying the ultimate ends of life with wealth, or power, or ease, or health, which though good are at bests means to further ends. The ends we are seeking are those of beings who are at once intelligent and animal, social and personal; they must be related to our situation with respect to society, to nature and to God. They are certain, therefore, to include knowledge and love, wisdom and virtue, justice and altruism; the development of bodily and emotional life, as well as that of the mind; service and love of God as well as of mankind. It is more difficult to harmonise all these elements; some would say that our end is a balanced human being, *mens sana in corpore sano*, while other would say, as Aristotle does at the end of his *Nicomachean Ethics*, that, since the life of the mind is the highest, we should try to exclude all else and 'play the immortal' as far as possible.[1] But I am not here concerned to develop a moral theory in detail; I only wish to indicate roughly its subject-matter, its data, its point of view and its method. It deals with the rational conduct of the life of man, in society, from the point of view of his duties and ends; its data are the experiences of moral life, such as moral obligation; its method is the reflective method, already met with in Chapter VII. It is not, however, concerned only with understanding; in morals, understanding is for the sake

[1] In *Morals makyth Man*, Gerald Vann has argued that Christians have the means to effect a synthesis of these views, both in theory and practice, by virtue of revelation and grace.

of practice, it is directed towards action; unity of theory and practice is of paramount importance. Right conduct, for good motives, leading to good men in a good society, is the aim of the study of moral philosophy; it is not meant to rust unused. The criterion of truth, too, is experience; as Aristotle says, in practical matters the truth is judged by the facts of experience, and moral views must be examined by being brought to the test of real life. We are not, then, in discussing moral philosophy, dealing only with a body of *a priori* notions, or of arbitrary commands; we are dealing with a rational body of thought, grounded in experience and concerned with the fulfilment of the potentialities of man.

That European moral philosophy has in fact been concerned with the problems and approach that we have mentioned could be verified by the most cursory survey. At the dawn of moral theory, Socrates and Plato make it clear that the proper life of human beings is not merely one of pleasure but is the pursuit of the good. Aristotle develops the theory of moral virtues and habits and gives the first systematic account of ethics. Aquinas applies to it his great principle of development, the progress from potentiality to actuality; a man has various potentialities, which he comes more or less perfectly to fulfil; the highest of them is union with God, a *summum bonum* which some of the Greek philosophers too had glimpsed. Kant emphasises the importance of duty; a study of the Utilitarians brings out the complementary importance of 'happiness' and the difficulty of defining it. Modern realists clarify the fundamentals, though often at the expense of unduly neglecting metaphysics (in the main stream of thought moral philosophy is dependent on metaphysics, in as much as it must presuppose some account of the human person and his situation). It is only after settling such fundamentals that one can essay an account of right action in various common circumstances, or discuss a code of duties and a set of rights to enable those duties to be carried out.

Moral causes distinct from psychological, biological and physical causes. We return now to consider the relevance of science to these questions. Moral philosophy, clearly, is not concerned with actions

due to sub-rational causes, nor with the bodily and physical agencies by which rational decisions are carried out; that is, it is not concerned with precisely the kinds of cause with which the natural sciences deal. *Per contra* the conclusions of the empirical sciences do not mention the fully rational aspect of human acts, which they leave out of consideration from the start. Empirical psychology deals with the sub-rational elements in us—the passions, emotions and senses; the effects of temperament and physique—all due to our minds being embodied. Biological science deals with the operations of the bodily organism as such. Physical science deals with the laws of inanimate matter. None of them deals with rational action as such; that requires a separate study, which is precisely moral philosophy. We must deny, then, that ethics can be based on natural science; for the natural sciences do not deal with the problems of ethics, namely those concerned with right actions performed deliberately and for the sake of good ends, but only with the *means* by which such actions are carried out and such ends effected. This has been a commonplace of European thought since the time of Socrates, who when he was condemned and about to die made some memorable reflections on the causes of human actions against the opinions of Anaxagoras, who, he said:

> '. . . seemed to me to have fallen into the predicament of a man who, maintaining generally that mind is the cause of the actions of Socrates, should then, when he undertook to explain my conduct in detail, go on to show that I sit here because my body is made up of bones and muscles; and the bones, as he would say, are hard and have joints which divide them, and the muscles are elastic, and so on. . . . And he would have a similar explanation of my talking to you, which he would attribute to sound, and air, and hearing; and he would assign ten thousand other causes of the same sort, neglecting to mention the true cause, which is that the Athenians have thought fit to condemn me, and accordingly I have thought it better and more right to remain here and undergo my sentence; for, by the dog, I think that these muscles and bones of mine (if

they had had any say in the matter) would have consulted their own interest and gone off long ago to Megara or Boeotia, if I had not thought it better and nobler not to play truant and run away, but rather to remain here and undergo whatever punishment the State may inflict. . . . If anyone should care to say that unless I had bones and muscles and the other parts of the body, I could not do what I would, that is well enough: but to say that I act as I do because of them, and that this is the way in which my mind acts, and not from choice of the best, why, that is a very careless and idle way of speaking.'

Moral philosophy and the inductive method. But in rejecting the possibility of an ethic based on natural science we have not yet given the reason that is most in place in this book: namely, that the inductive method is totally unsuited both to the subject-matter and the point of view of moral philosophy. This subject-matter is rational life; the point of view is the moral goodness of the human agent and his ends, and the moral rightness of his deliberate acts. The proper method for moral philosophy must accord with these. But the conclusions, procedure and presuppositions of the inductive method are all inappropriate to them. (*a*) The inductive method gives us generalisations about the course of phenomena. But in moral philosophy we do not seek such generalisations. Moral principles do not describe how people do in fact behave; they lay down how they ought to behave. They are not descriptive, but normative. (*b*) An inductive generalisation is supported by numbers of instances. But it is not numbers of instances that tell us whether an action is right or wrong, or a motive good or bad; it is insight and reason. No matter how many people poison their mothers or hate their brothers, it remains wrong to do so. A single instance of rational action, provided it were thoroughly understood, would be enough to call our attention to the principles of ethics. (*c*) Again, the inductive method presupposes that behind the phenomena it deals with there are necessary connections. But in moral life there is no iron necessity; one can always refuse to do right and prefer to do what is evil, like Iago. Man is not like subhuman nature,

which cannot choose but follow laws. Choice, not necessity, is the first great fact in moral life. 'I ought' implies not only 'I can' but 'I need not'. The inductive method, then, is not applicable to the principles of morals. The method that has in fact always been followed is the reflective one—reflection upon the moral aspect of rational life, and construction with the help of reason of a coherent interpretation, followed by comparison with the facts of life. The moral philosopher appeals to experience and learns from observation, but he does not do so in the same way as the scientist; he judges actions as right or wrong, and characters as more or less fulfilling the potentialities of humanity.

A 'scientific' ethic. It has been suggested that we could apply scientific method to the construction of a new ethic as follows. As in science we infer the properties of causes from their effects (so the argument runs), so in ethics we should judge of the worth of an action by its results, which are to be determined by observation and generalisation as in natural science. The grain of truth in this argument will appear in the next section; here I wish to point out that, apart from the looseness of its analogy, it provides no basis whatever for ethical theory. For, how shall we judge the results of an action? Either we must judge them morally, in terms of goodness (ultimately, of the good of persons); and in that case we have not avoided the need for an independent ethical theory. Or we shall judge them by expediency—by their contribution to riches, health, comfort and so on; and in that case we have merely denied that there are ethical problems, and waved away all the data of human life that convince us that there are duties and ends, which are moral realities, *sui generis* and not to be conceived in terms of non-moral concepts. Again, the morality of an action cannot be judged solely by its results. We may not do evil that good may come, nor use evil means to a good end; we may not indulge in hatred while doing an act that may be right in itself, such as punishing a traitor. The reason is that the end, the means, the circumstances and the intention are all important in the moral estimate of a human action, as well as its likely results. To drive a car recklessly is wrong in itself, though an

accident only occurs once in twenty times, because it is wilfully careless of others' welfare. To shoot suspected criminals without trial would be wrong in itself, even though one got rid of a murderer four times out of five, because the end does not justify the means if the means are in themselves evil. Thus the ingenuous suggestion which was to be the basis of a new ethic leads straight to expediency and to the denial of the essentials of ethics.

Moral practice and science. Have the conclusions of science then no relevance to moral life? Certainly they have; not indeed to moral principles, but to moral practice, to the application of the principles in life. For often it is to science that I must turn when I want to know the result of some action that I am considering; often it is science that enables me to choose an effective means to some end that I am pursuing. I want my child to be healthy; medical science tells me that *inter alia* vitamin C is necessary to health and that it is found in orange juice; in the absence of other sources, I conclude that I ought to give my child orange juice. A statesman wants (let us say) stable prices and an open world market; economic science will suggest various plans for achieving these aims. Science is not concerned with the morality either of the end or of the means; but it tells us what means will be effective to a given end. Science may thus enable us to do great good that we could not otherwise achieve for lack of material means. This is most evidently true of medical science; the relief of pain, malnutrition and psychological disorder is self-evidently good. Modern industry, moreover, rests on the application of science, and in so far as it is a blessing science is a part cause of the good that it works. But this topic belongs to the next chapter. It is time to turn to some objections.

DARWIN, PAVLOV, FREUD, FRAZER

It may be objected by some that all this talk of rational life is out of date. Are not the conclusions of science relevant to our view of the nature of man and hence of the life he should lead? And has not the old conception of man been put out of court by the accumulated evidence of evolutionary biology, anthropology,

behaviourism and analytical psychology? If we are to have an ethic compatible with modern science, must it not be a new ethic, based on the direction of evolution or on the conditions of psychological health? I do not think that such theories would be put forward by anyone who understood what moral philosophy is about; the scientific work cited has no bearings on the principles of ethics. Let us outline the conclusions that can legitimately be drawn from it.

(i) *Evolution and 'evolutionary ethics'*. That the bodies of living organisms have reached their present forms by a process of evolution in the sense of the modern theory—that is, by changes due to mutations as well as minor variations, by the inheritance of such variations, and by competitive selection favouring types with variations advantageous in a given environment—is a strongly based scientific theory, supported by a range of evidence from palaeontology to experimental genetics. It is also a well-established generalisation that with increasing complexity, and especially with increasing size and complexity of brain and the development of a central nervous system, the ability of animals to learn from experience increases, and that apes can sometimes even deal with new situations in a way that recalls reasoning, though different in kind from reasoning since there is no warrant for supposing that it requires concepts. However, to conclude that organic matter can spontaneously evolve into mind, that men differ only in degree of cunning from other animals and that biological evolution settles the laws of man's behaviour, would be completely unjustified by the evidence of natural science and in conflict with the evidence used by metaphysics and ethics. When we say man is rational we mean, among other things, first, that by comparison and abstraction he can apprehend concepts or universals (like redness, quantity, duty) common to a number of instances, and can reason by means of these universals in the absence of the instances from which they were derived; that he can draw conclusions from evidence; that he can formulate principles and control his actions in accordance with them, directing his life towards distant goals, selecting means to these ends and

changing the means in accordance with experience. It is these powers that are the source of the other characteristics that differentiate man from other animals—language, law, art, religion and so on. Rationality makes man different in *kind* from other animals. That a highly developed organism and brain are necessary to reasoning, I readily grant; that they are a sufficient condition for rationality is quite another proposition, and one that has no support in experience. Accordingly I do not believe that the theory of evolution of organisms weakens the view that man is rational—a view derived from evidence other than that used by biology, and indeed presupposed by biology, as by all science, since if man were not rational he could not construct sciences based on evidence and claiming truth. I propose, therefore, to believe that the human body was very likely developed from those of pre-human organisms, in accordance with the evidence up to date of natural science; and also that man is rational and different in kind from other animals, in accordance with the evidence used by philosophy and common sense. The first is a well-supported hypothesis of science (and, despite a common belief to the contrary, it is not opposed to an orthodox interpretation of Genesis); the second is a condition of all thinking and all rational action.

It has been suggested that we ought to base our notions of moral progress on the theory of evolution. Right action, it is proposed, is that which is in accord with the direction of evolution. If what I have said be accepted, there is no need to deal with this notion at any length. Even supposing that the current direction of biological evolution has been discovered by biological science, it still cannot be assumed that rational behaviour is governed by the same laws as biological development; indeed, the contrary appears to be the case, since in rational life cooperation replaces competition, and nature's weaklings are protected. If, however, the concept of evolution is stretched to cover more than biological change and to include moral progress, then we can only discover its direction by taking account of moral philosophy, which thus cannot be supplanted. Rightness is

rightness, goodness is goodness, and neither can be analysed in terms of pleasure, wealth, power, expediency, adaptation to environment or any other non-moral concept. I do not believe that those who have tried to extract ethical principles from evolutionary theory have formulated even the problems of moral philosophy, and they have certainly provided no solutions. They have simply tried to make natural science do the work of philosophy, and since its method is unsuited to the task the results are not impressive.

(ii) *Psychological materialism.* It would be tedious to narrate the arguments of the behaviourist school and of certain exponents of psycho-analysis, in favour of the view that man's behaviour is not controlled by reason. The alleged evidence is well enough known and adequate short accounts exist. Apart from the consideration that if these arguments are not themselves the products of reason they have no claim to be believed, the obvious comment is that the evidence they use was not drawn from rational behaviour. The work on conditioned reflexes initiated by Pavlov showed that much of human behaviour is automatic and sub-rational. I readily grant that this is so, and am glad of it, for my reason has better things to do than to attend to trivialities that my body can look after for me. Freud's work showed that people can suffer from psychological diseases and that the rational part of the person may then be more or less submerged and so his behaviour largely determined by sub-rational causes. This is perhaps no great surprise to anyone who has so much as read *Othello* or *Hamlet*; what is surprising is to find people concluding that *all* behaviour is irrational, when the evidence proves nothing of the kind and when psychiatrists in practice labour to restore to their patients the full use of their rational powers.

It is relevant to recall some of our conclusions about the status of inductive arguments. A theory in natural science is not implied by the evidence adduced for it; it is only supported as more or less likely. If an alternative hypothesis can 'save the phenomena' it is equally credible; if it is supported by additional evidence from other fields, it is to be preferred. Now to hold that man is

rational and can direct his life by reason, rather than being swayed entirely by unconscious forces, is compatible both with the data on which the long tradition of moral philosophy is built, and also with the data produced by modern psychological study. The view I would maintain is that some of the actions of a man are human acts in the full sense, rational and responsible; others are done in accordance with rational decisions, but through perseveration, without adverting explicitly to the reasons for the decision; others are due to sub-rational causes; and excessive anxiety, fear or shame may have lasting effects that cause the reason to be partly or even wholly overborne by the sub-rational part of human nature. This view is more broadly based than the materialist hypotheses, and saves the phenomena just as well. Again, we recall that theoretical interpretations commonly use analogies. Now it is certain that a man is in some respects analogous to a dog or an ape; but from that evidence we cannot conclude that he is analogous in all respects and has the same nature. The analogy breaks down at the vital point: man has powers that other animals have not. These considerations from the method of science, then, reinforce our conclusions that the data of modern psychology do not, as has been so often declared, support the view that man is not a rational being. Apart from the self-contradiction in using rational argument to deny rationality, the evidence as a whole supports a wider view, and it is not wise to maintain the narrower one.

(iii) *Anthropological materialism.* There is a widespread belief that the basis of ethics has been cut away because the comparative study of social systems by anthropologists has shown that the codes of behaviour of primitive peoples differ greatly from culture to culture and are influenced by climate, economic structure and other non-moral factors. It is claimed that this shows that moral philosophy can have no general validity. This is not a new argument; Herodotus noted that the Greeks burned the bodies of their dead and were horrified at the notion of eating them, whereas some tribes of Indians always ate them and exclaimed aloud at the notion of burning them; and he, too, drew the shallow

conclusion that 'convention is king over all'. Such variations in ethical beliefs are in fact neither surprising nor disconcerting to the moral philosopher. They are not surprising, because in primitive societies conventional conduct may well be based on inadequate views of man, which are very common; and they are not disconcerting, because moral philosophy does not depend upon correct application nor upon universal use for its validity, and is more interested in the fact that in all human societies the difference between right and wrong actions, and between good and bad lives, is appreciated, and given detailed form in codes of law, even if these laws differ about which actions are right and which lives are best. The fact that many primitive peoples have false ethical beliefs need not discourage us, since we have advantages that they lack; namely a highly developed tradition of moral philosophy, embedded in Western culture and history—not to mention the Christian revelation, to which, however, we are not here appealing. In moral philosophy, then, we are not dealing with mere conventions relative to a social milieu, but with fundamental properties of man, arising from his nature; manifested indeed in different ways, but springing from his manhood and not from particular environments.

CONCLUSION

To sum up. Science provides none of the general principles of the good life. But it can be integrated into the good life for scientists, by reason of its rational spirit and its discipline of the will. Its conclusions are sometimes important in practical life, because they state the means necessary to certain material ends, and the effects of certain actions; but they are not relevant to the more fundamental questions dealt with by moral philosophy, and attempts to base the principles of ethics on science or scientific method simply leave out the essential factors.

CHAPTER X

Society and Science

IN the last chapter we saw how science can form part of the good life for scientists. But science is supported by society, and this not only in voluntary and independent institutions, like the ancient universities, but in organisations maintained by public funds. What, then, are the values of science to society at large?

This discussion is not made easier by the prevalence of a confusion between science and the application of science; between the understanding of nature and the manipulation of it. The confusion is not without excuse, because in the industrial organisation of economic life a large proportion of men who leave universities with a training in science must bend their knowledge of nature to the control of matter to fulfil some technical requirement. But this is one of those occasions when a small mistake at the beginning is a grave error at the end; lack of clear distinctions at the start leads to a distorted conception of the place of science in society. Much that has been written under this title is really about the place of technics in society, with science considered only as part of the basis for technics. But this topic raises problems quite different from those concerning the place of science itself in society. It is necessary, therefore, to start by making some essential distinctions. We may first distinguish three main fields in which a man with a training in science may find himself working: (i) pure science (whether teaching or research); (ii) applied science; and (iii) technology.[1]

'PURE SCIENCE' AND 'APPLIED SCIENCE'

'Pure science' denotes the study of nature for the sake of the good resulting simply from the understanding of nature, apart

[1] Many scientists who took part in war-time researches have had experience in all three fields; I believe that they will recognise as accurate the essential features of the following account.

from any material benefits. Its method is to experiment (or observe), to generalise, and to interpret the results in terms of some hypothesis which, even though temporary, confers some degree of understanding. 'Applied science' uses the same method and arrives at the same sort of knowledge; but the knowledge is sought primarily for the sake of its applications. Between pure science and applied there are many affinities. The material they work on is the same; the scientific methods used are the same; the theses produced are similar; there may be close contact between workers in the two fields. Moreover, men working on applied science may themselves be more interested in the knowledge gained than in its application, and may have as good an understanding of nature as their academic counterparts. No distinction can be drawn between pure and applied science in terms of difference in training or competence of workers; or in organisation; or in method, which in both studies is simply that of natural science; or even in the immediate outcome of the work, which for both is a new understanding of nature. None the less there is a difference, which is not at all subtle, between the general outlooks of men representative of pure science and of applied science; and the reason for it is to be found in the difference of the ends which are served by the two types of work. The end of pure science is understanding, and the personal advance in wisdom and virtue which should be the outcome of the rational study of nature. The end of the application of science is control of the behaviour of matter, by means of this understanding: the manipulation of nature for the material welfare of men.

This difference of ends is not a sterile distinction. It corresponds to an important difference in outlook on the part of many of the scientists concerned; to a difference of orientation in the choice of subjects for investigation, and in the emphasis adopted in exposition; and ultimately to differences of opinion about the directions which 'fundamental research' should take. It is indeed the only perfectly precise and clear-cut distinction that emerges from the discussion of pure and applied science. Scientific men, institutions, and policies may reflect one or other of these ends, or both in

varying proportions; and we are left with the distinction of ends as a fundamental touchstone, whose application may often be a complex matter.

TECHNOLOGY AND SCIENCE

The same difference of ends also distinguishes technology from science. Technology is the application of the knowledge won by pure or applied science, in working out and practising techniques for the control of material nature; and whereas scientific research is concerned with winning and organising knowledge, technological research is concerned with the application of that knowledge for extra-scientific purposes. Some people—even some men of science—have had difficulty in finding the basis of the distinction between technology and the sciences. There are indeed considerable affinities between them. They both deal with the material world and with the same kind of knowledge about it; they both use experimental methods in research; they both employ men trained in science; they use similar vocabularies. Technology depends upon science for the knowledge which it applies, and sometimes provides the raw material of scientific advance, namely new observations or other stimulants to investigation. No distinction can indeed be made in terms of subject-matter, or training of personnel; nor, as things are, could the actual study of science easily be separated from technology, on which it has come to depend rather intimately for materials and apparatus. Yet it is impossible to maintain that science and technology are identical without depriving distinctions of their meaning.

The fundamental distinction is again that of ends; the whole of the preceding discussion on applied science holds good also for technology, whose end is clearly the control of matter. The resulting differences from pure science, in personal outlook and in organisation of work, are even more marked. For instance, a technologist's problem is assigned to him and he is expected to provide a solution; whereas in science it is essential that there should be some freedom of investigation. This leads to a complete difference in the dialectic of development: that of science follows

its own inner needs, the call of truth; that of technology follows the material needs of the public. For instance, the scientific understanding of the phenomena of electricity and of radiation developed according to the normal principles of science, quite distinct from the principles of development of electric lighting which depends upon it.

A second distinction concerns the method of investigation. The method of technological research consists in applying the results of science as far as possible and, where they are insufficient, conducting *ad hoc* experiments. If the system concerned is simple enough, and if the relevant scientific work has progressed far enough, it is only necessary to verify a result predicted on scientific grounds. But it often happens that too many factors are involved, or that scientific data are not available over a sufficient range, or that several phenomena are concerned simultaneously; for these or other reasons it may be necessary to try various expedients until one is successful. In such experimental investigations there are several important analogies with the experiments of science: variable factors are controlled, and the correlation of variables is employed. But the method as a whole differs radically from that of science. The experimental part of science, being directed towards understanding the system under investigation, is essentially connected with the other part of scientific method, namely the formulation of explanatory hypotheses; an experiment which leads to no new understanding is a failure, and experiments are commonly designed in the light of some hypothesis in order to verify it or disprove it. The experimental part of technology, on the other hand, except in so far as it makes use of knowledge already won by science, uses simply the method of trial and error; it does not as such lead to any new understanding of nature. Technology is usually content to tabulate observations in a form convenient for achieving certain specific practical aims; it does not seek to understand the relations between the observations. Technology presupposes scientific understanding, but does not normally contribute to it. Tables of quantitative data, however extensive and accurate, do not constitute scientific knowledge,

though they may be raw material for the scientist; just as the finest astronomical tables are no more than a preliminary to a science of astronomy.

THE DISTINCTION BETWEEN THE ENDS OF SCIENCE AND OF TECHNICS

In distinguishing between the ends of pure science as such and of scientific technics as such, I am not of course implying that science should not be applied and used for the technical control of nature. On the contrary, it is tenable that, if knowledge can be applied for material welfare, then there is prima facie a moral obligation to apply it. What I am maintaining is that science has an end, a use besides its use in technics, namely its use in promoting the development of people, through the increase in understanding that it makes possible—in facilitating the growth of the mind and will through the exercise in scientific life of intelligence, initiative, discipline and so on. No doubt the ends of technics are complementary to this, in so far as material welfare can itself be used as a means to personal development, and is indeed a condition of it; but these ends are none the less clearly distinguishable, and the distinction is important because the place of science in society is too often considered in the narrow setting of economic welfare alone, so that the potential contribution of science to the growth of the mind and will is under-estimated. I do not in the least advocate that the scientific world should be self-contained and oblivious of human needs; what I am saying is that those needs are not only economic but concern other aspects of men as well, that within human welfare it is possible to distinguish (without separating) more than one important aspect, and that correspondingly a distinction should be admitted between the ends of science and the ends of technics as such.

THE PLANNING OF SCIENCE

The application of this argument to the question of the 'planning of science' may be briefly indicated. Planning in science and planning the application of science are two different things.

Research in technology, and to some extent in applied science also, is fittingly directed towards solving problems indicated by some outside authority—the problems of health or of national defence, for example. But since the end of pure science as such is knowledge, rather than control, it must follow its own inner dialectic and cannot be directed by any authority external to itself. Moreover, as is often pointed out, any attempt at external direction is fatal to the quality of the work produced. The part of external authorities is to provide facilities rather than to apply compulsion. The same applies to the planning of science from within: projects for allotting work and preventing overlapping by compulsion are not in the true spirit of science. The best organisation yet found for scientific research is the small group gathered round an experienced, unselfish, independent, original scientist; the ideal size of the group depends on his ability and personality and other imponderable factors. Scientific research to order is not a practicable proposition.

TECHNICS AND THE DEVELOPMENT OF SCIENCE

If we keep in mind the differences of aim and method outlined above, it does not seem possible to maintain (as some would like to maintain) that science and technology are indistinguishable as well as indivisible. A popular view of the development of science is based on the presuppositions that the true function of science is to promote material welfare, and that its development has been, and ought to be, controlled by the material wants of man. This view does not stand up well to historical examination, and it appears that its failure is due to its over-simplified principles. Science no doubt owes to technics some of the empirical data which are its raw material, and the knowledge accumulated by craftsmen has no doubt been one influence on its development; but, as we noted above, the material of science is not science itself, and the specific difference of science is precisely that it is not content with what satisfies technology, but must go on to try to understand; thus science and technics become distinct in aims and methods. Empirical data are not science, nor can technics

be a sufficient cause of science, if the zest for understanding is lacking.

The common account of the influence of society upon the scientist is likewise over-simplified. It is true, and important, that scientists are part of the social organism; they are not altogether insulated from the movements of their time. But it is an over-simplification of this truth to say that it is the material needs of society (or of its rulers) that are the predominant influence on scientists. It leads to such historical absurdities as the contention that Galileo studied mechanics in order to improve the craft of gunnery—despite the evidence of the documents that his interest were concerned with Aristotle's laws of motion and the Copernican hypothesis.[1] It would be more accurate to say that the most important facet of the influence of society on scientists is the influence of the intellectual climate, and in particular of current beliefs about nature. Science develops because men are inquisitive and wish to understand natural phenomena; the growth of science, therefore, depends on a mental climate in which it is assumed that phenomena are intelligible; physical science depends on the further conviction that the way to make them intelligible is to measure them. Such beliefs were not widespread in Europe until after the twelfth century; there were needed such great changes in thought as those brought about by the realism of St. Thomas Aquinas, the interest in numbers of the neo-Platonists of the later Middle Ages, and the nominalist interest in empirical generalisation. The common materialist view of scientific history, then, is over-simplified; it should be replaced by an account of science in the wider setting of its relation to thought, art, literature and religion, as well as to practical needs.

THE 'SOCIAL FUNCTIONS' OF SCIENCE

Having now cleared the ground we can attempt an answer to the question of the 'social function of science'. There are in

[1] It was even argued by an enthusiastic young marxist that the wave-particle dilemma, referred to in Chapter II, was part of a general crisis in current physics, attributable to its bourgeois presuppositions, and parallel with an economic crisis due to the same root causes in the capitalist countries. (Christopher Caudwell, *The Crisis in Physics*, Chapter X (1939).)

fact two quite distinct ways in which men trained in science can discharge their responsibilities to their fellows. One is through the application of science to make easier the material conditions of life. But the ease and frequency with which science is misapplied seem to make this inadequate as the sole justification for the existence of science. Science is just as useful for killing as for curing, as its mobilisation for war has shown us; whether its applications have so far, on balance, done more harm than good is a disputed point; so that its usefulness is not an unassailable ground for its existence. A stronger case can be made for science as a social force in terms of its approach to truth and to rational thought and conduct.

(i) *Science calls attention to the primacy of truth and reason.* If, as was argued in the last chapter, science could be made a real school of rational life, in virtue of its being a type and microcosm of rational procedure, it would necessarily contribute to the personal development of those who follow it. Life is a unity; the scientific part of life affects the rest. A scientist who makes a proper use of his science can become, in and through his work, a better man: one in whom reason is better developed, and who appreciates better the fundamental values. Such a man is an asset to society, for he can help to uphold the rational values upon which civilisation is based. The vitality of society depends on the vitality of individual people and on their intellectual and moral ideals. If a scientist really understands the bearings of his work, he can exert a useful influence in society, and this not only by diffusing the knowledge of nature, but by upholding the claims of reason, as against force or prejudice or passion. Thus those whose work consists primarily of teaching or research in pure science can fulfil a highly important social function simply by their contribution to the conservation, advance and propagation of scientific life, because they thus call attention to the fundamental values of rational life.

The most fundamental of these values is respect for truth. It should not be taken for granted that respect for truth is ingrained in us and stands in no danger. In the first place, truth is always

more or less in danger, always liable to be submerged by the forces of confusion; the struggle begins again with every birth. To-day there is, moreover, the possibility of an attack on truth (or rather an extension of an attack already begun) arising from the tendency to a merely political view of man; with this we shall deal later. To these dangers scientists—in common with philosophers, artists, historians and divines—should reply with a living expression of the claims of truth. The social influence of science should promote fidelity to fact, critical scrutiny of alleged evidence, and responsibility in interpretation. It may even be that natural science will be one of the strongest supports of respect for truth, for science has an advantage over other representatives of reason in that so long as it remains alive at all it cannot be grossly false to the true rational spirit. For in science there is seldom much dispute about the facts; false science can be disproved by experiments reproducible at will; moreover, it usually fails if attempts are made to apply it. Most other studies, as may be seen from their condition under totalitarian governments, are liable to perversions that are much more difficult to eliminate, because the test of experimental verification is not applicable.

It is the spirit of science, the mental climate that it promotes, that I am saying can influence society in favour of reason. I do not say that any particular conclusions of science can influence moral principles; that would be contrary to all that is argued in this book. Science cannot issue directives to society, for it is not competent to discuss the ends of society. In relation to the great social purposes—such as peace, justice, liberty—science is instrumental; it is not normative, does not lay down what ought to be. If scientific method is applied outside its own field, if the attempt is made to use one rational method for work appropriate to another, the result is always confusion and, at worst, disaster. To make its full contribution in society, science must respect the fields of other studies; conversely, it relies upon those studies being in a healthy condition. In concrete terms, this means that a scientist who is ignorant of philosophy, history, art and literature, will not be able to speak for reason with the power that he should.

His ignorance will render his study unfruitful and he will in some measure fail the society in which the prestige of science at present stands so high.

In this account of the primary social function of science, the attempt has been made to retain what was positive in the older apologia of science, which represented its value as due to its loyalty to truth, and to complete it by re-stating it in terms of personal life and the good of persons. At the same time the view outlined cannot be accused of favouring a selfish or irresponsible attitude. Whatever we do, scientists or technicians, we must serve our fellow-men ; but it is as essential for a healthy society to contain some men who by profession must put truth first, as it is to have technologists who can contribute to material welfare.

(ii) *Science is applicable.* The second reason why science is valuable to society is that the knowledge of nature can be applied to the control of matter; it can provide us with techniques for improving health, reducing drudgery and increasing material comfort. (This is no doubt the main reason why it is in fact valued by politicians and the general public.) Many have stressed the importance of these potentialities of the application of science, which are now fairly widely appreciated and call only for relatively brief mention here. We may well have reservations about some of the applications of science in the past, especially in increasing the range and speed and indiscriminateness of war, and in contributing to the dominance of industrialism in Britain and elsewhere—for it seems that industrialisation has overreached us in parts of the west, and become master rather than servant. However, at least we now know its capabilities, and we could, if we tried, turn without losing its benefits to a better balance between industry, agriculture and craftsmanship. In the present state of the world the application of science could be directed to satisfy real needs; there is immense scope for really beneficent applications of science. There is no doubt that unnecessary malnutrition and ill health afflict a large proportion of mankind; that men's work is too often mere drudgery; and that the conditions of life of the poor of many nations could be eased in many

ways. The battles against disease, destitution and ignorance are always with us, and science is a powerful ally; perhaps the most necessary ally after love and understanding and common sense. If I do not deal at length with these matters, it is because many are already concerned for them, while there are relatively few to stress other factors in human welfare that are no less important. We ought not to accept uncritical views of applied science as the saviour of society, such as that described by the Webbs in *Soviet Communism*; we should seek to take a wider view of science, based on a deeper understanding of the vital needs of men in society.

Parenthesis on 'marxist' views. At this point a note on the body of thought that may be loosely called 'marxist' may be opportune. There is of course much that commands wide agreement in the marxian criticism of monopolistic capital as a means of exploitation—indeed, on the critical side, marxist thought on this matter is in considerable agreement with the papal encyclicals on the social question.[1] The realist standpoint of marxist philosophy, its interest in the process of becoming and development, its insistence on the unity of theory and practice and on our ability and duty to change the world in accordance with principles —all these are congenial to the realist philosophy on which the views outlined in this book are based. They are not nineteenth-century inventions; they were familiar to Aristotle and to all who

[1] For instance: 'Hence by degrees it has come to pass that working-men have been surrendered, isolated and helpless, to the hard-heartedness of employers and the greed of unchecked competition. The mischief has been increased by rapacious usury. . . . To this must be added that the hiring of labour and the conduct of trade are concentrated in the hands of comparatively few; so that a small number of very rich men have been able to lay upon the teeming masses of the labouring poor a yoke little better than that of slavery itself.' (Pope Leo XIII, *Rerum Novarum*; cf. Philip Hughes, *The Popes' New Order*.) 'Immense power and despotic economic domination are concentrated in the hands of a few. . . . This domination is most powerfully exercised by those who, because they hold and control money, also govern credit and determine its allotment, for that reason supplying, so to speak, the life-blood to the entire economic body, and grasping in their hands, as it were, the very soul of production, so that no one can breathe against their will. This accumulation of power, the characteristic note of the modern economic order, is a natural result of limitless free competition, which permits the survival of those only who are the strongest, and this often means those who fight most relentlessly, who pay least heed to the dictates of conscience.' (Pope Pius XI, *Quadragesimo Anno*; cf. Philip Hughes, ibid.) 'Along with the constantly diminishing number of the magnates of capital, who usurp and monopolise all advantages of the process of transformation, grows the mass of misery, oppression, slavery, degradation, exploitation.' (Karl Marx, *Capital*.)

have studied him or his successors, though little regarded at the time when Marx and Engels were writing. The root trouble with dialectical materialism is that its incipient realist approach is not thoroughly carried out; it is cut short by an *a priori* rejection of certain kinds of evidence. Briefly, it is realism *manqué*. The most important example of this has been mentioned in Chapter VII, namely the refusal *a priori* to interpret the evidence that God exists, or to examine the analysis that leads to that conclusion. This limitation of marxist thought has its worst effects in social theory and practice; for, if man is not made by God, and if human authority is ultimate, there is no compelling reason why the state should allow any rights to the individual man, and accordingly man is treated as if he were merely a politico-economic unit, instead of as a person with definite rights; so that the state can disregard his rights and use him, in its schemes of 'social engineering', as a mere means, as so much dung for a future crop. Thus, on the constructive side, the remedy offered is as bad as the disease; atheistic communism and capitalism are at one in their denial of the rights of man as such. With this low view of the nature of man goes a tendency to narrow the ends of science to those of technics, and to a correspondingly narrow view of the place of science in society. It is at bottom the apriorism of marxian metaphysics that is the trouble, that limits and spoils the realism of the materialist approach, so promising at first sight. The realist metaphysical tradition is not truncated in this way and can accept every kind of evidence; it has, moreover, enabled us to give full weight to the other elements of truth that we have indicated in dialectical materialism, while avoiding the errors due to its apriorism.

TECHNICS IN SOCIETY

The problems concerning the place of technics in society are quite different from those concerning the place of science in society, and a scientist who discusses them is in the position of a layman. Here I only wish to point out that technics cannot lay down its own ends; it must be directed by ethics. Technical

considerations are important, in that they indicate what can be done; but ethical considerations are overriding, in that they indicate what can best be done or what ought to be done. Technique is quite neutral and can be adapted to very diverse ethical conceptions; for a given purpose several techniques may be possible, and the choice between them may have to be decided on grounds that are not technical but ethical.

The importance of ethics in this field, as well as technical considerations, is shown by the two great problems, or rather sets of problems, that arise when economic life is dominated by industry. One set of problems arises over the ownership of the means of production. This ought not to be concentrated in a few private hands, for that gives a few men too much power over the many. Is state ownership the solution, or will it in practice lead again to the concentration of power in another small set of men? Would it lead to compulsory direction of labour, with a consequent tightening of the mechanical bondage of industrial life? How far could we go with a third possibility, the wider distribution of ownership, either individual or co-operative, with its great advantages for economic freedom? This raises all the problems of a directed economy. Should direction take the form of state planning, with compulsion; or could economic effort be canalised by preferential credit arrangements and other facilities? How is general direction best reconciled with freedom of choice for all concerned? And so on. The conclusions of science and technology may be concerned in the solution of such problems, but only in so far as they enter into the preliminary fact-finding. The other questions are ethical, inescapably connected with philosophy and ultimately with our view of man; for instance, if we think, as Aristotle did, that some men are slaves by nature, we shall reach different conclusions from the Christian. Science is concerned only in so far as it stands for reason, full information and rational judgement.

The other set of problems is almost equally important, though relatively seldom mentioned. These are the problems presented by the very nature of work in industry, and by the effect

of such work on the minds of men in a society whose tone is set by industrialism. Working-class life in Britain (and increasingly in other countries of the west) is dominated by employment in industry. This industrialism is becoming more and more dependent on technology based on science. Several consequences of this arrangement are of the first importance. Industry depends increasingly upon a relatively small group of men with technical knowledge; these men may come to acquire a measure of power which they are in no way trained or qualified to exercise. The mass of working men, deprived already of their economic independence, become tools carrying out processes that they cannot hope to understand. They must obey directions and carry out assigned tasks, which are reduced as far as possible to a mechanical routine; there is no place for the responsibility and skill of the craftsman. Some would have this degradation extended to their children; education, we are sometimes told, should abandon its traditional role of helping the child to develop into the complete man, aware and responsible as a member of church and state, and become a 'preparation for industrial life'—that is, aim to produce men and women who will meekly give themselves up to be factory fodder. It is urgent that we should aim to achieve a better balance of rural and town life, of craftsmanship and machinery, of small ownership and factory production. (The ease with which electrical power can be distributed would seem to permit a reversal of the nineteenth-century concentration of production in industrial towns.) This set of problems needs far more attention than it has yet received.

SCIENCE AND THE CRISIS OF OUR TIME

It is often said that our civilisation has reached a crisis because our technical knowledge has increased and is increasing faster than our ability to use it properly. The world has great industrial power, but does not know how to avoid economic instability; the nations have rapid communications, but cannot agree about what is to be communicated; they have good transport, but when it has brought them together they do not love one another; they

have devastating weapons, but do not always use them in the cause of justice. No doubt this is all true, but surely it is a statement of symptoms rather than of the disease. Moreover, it confuses the diagnosis by mentioning only the less fundamental symptoms. Far more significant for our crisis are signs like the new contempt for the pledged word, leading to a whole technique of deceit that was characteristic of the Nazis and has by no means died with them; the loss of respect for the ideal of justice, so often denied in the interests of 'ideology' or mere hatred; the decline of respect for truth itself where political opponents are concerned or where ideologies are to be instilled. The major crisis is not merely a matter of squaring technical progress with a slightly lagging advance in ideals or in social techniques. It is nothing less than a matter of saving the ideals themselves, and the conception of man that goes with them.

The fundamental struggle to-day is for the reassertion of the conceptions of man and society that we derive from the best elements of the European tradition. The Greek philosophers and the Roman lawyers and moralists made considerable progress towards a conception of man as an intelligent, responsible and moral being, capable of following truth and doing justice. For all that, their economic systems were based on slavery, and the ideal man of the wisest of the ancients was a snobbish prig whom we should not care to meet to-day;[1] as an historical fact, it was Christ who outlined the highest conception of man and the highest way of life, which we may find developed in the gospels, from the sermon on the mount to the great discourse reported in the fourth gospel, which lays down the claims of love and finally indicates both the truth and the way to it. In the succeeding centuries the resulting conceptions of man and society were pondered, expanded and developed in their diverse aspects—economic, political, moral, intellectual, mystical. The political aspect, for instance, is embodied in the English common law, which presumes that the citizen is *homo liber et legalis*, the free and law-abiding man, with the duty of living according to reason, and the corresponding

[1] The 'great-souled man' or 'man of lofty pride' of Aristotle's *Nichomachean Ethics.*

right to freedom of thought, of speech, of association and of religion. Spiritual values are presupposed; the moral and political aspects are not separated. Many who do not believe in Christian doctrine accept important elements in this view of man, holding that man is a rational being, meant for liberty in an open society, and that spiritual values hold the primacy. Respect for truth, respect for justice, respect for the human person—these are part of the heritage of Western man.

To-day, however, this conception of man is too often forgotten, in favour of a conception that is narrowly political and economic. Too often we think and behave as if a man were merely a toiling and consuming animal subject to a government. We tend to neglect man as creative, man as a friend and lover, man as a member of a family, man as a responsible being, man as a child of God. We tend to forget that life has many aspects besides those which are the state's affair, and that to identify society with the state is a mere confusion; that the state should not be all-pervading and omnicompetent, but should leave room for innumerable voluntary associations, like those that have given greatness to the English tradition in education, law, industry, the professions and religion. For the common-law conception of the free and responsible man is substituted, by industrial capitalism, the conception of man as a 'hand'; by Leviathan, the conception of an 'insured person'. We have descended far from the view that Shakespeare put in the mouth of Hamlet in the famous passage: 'What a piece of work is a man: how noble in reason; how infinite in faculty; in form and moving how express and admirable; in action how like an angel; in apprehension how like a god! The beauty of the world, the paragon of animals!' We put up with low views of man and society, as of truth and justice, because we have forgotten the greatness of our destiny.

Part of the blame for this situation rests, not indeed with science, but with the misinterpretation and misuse of science. Inordinate science-worship has led to the debasement of the conception of man in the various materialisms that claim as their support physics, biology or psychology; it is forgotten, in these *naïve* schemes,

that the scientific method enables us to examine only a part of reality from a particular angle, and cannot deal adequately with the questions most important in human life, and that a view of truth that is restricted to knowledge of the kind gained by natural science is radically incomplete. Again, the misuse of the application of science in developing new weapons has led to the material ruin and desolation that now shames the race of men, and to a situation whose natural results are nihilism and despair. We cannot lay these evils at the door of science itself; but they are partly due to misconceptions about its scope and to misuse of its technical applications. A more exact view of science would remove at least one of the historical causes of the spread of inadequate estimates of the nature of man.

The reason why we must reject the low view of man and all its consequences is not only that it leads to injustice, but that it is untrue, and breeds untruth. It is untrue, in that it is dangerously incomplete, because it neglects important facts about man—it ignores the experiences that have always given rise to philosophy, literature and art, not to mention religion. It breeds untruth, because it leads to neglect of these same pursuits, the great treasuries of human values. Moreover, it opens the way to the omnicompetent state; and in proportion as governments assume absolute dominion over their subjects, they are tempted to regard the state as the source of all values and to doctor the truth in the interests of expediency. They become so much concerned with the question 'What is it expedient for the mass of men to believe?' that the question whether it is true or not takes second place. Himmler proclaimed that he did not care whether the theory of nordic superiority was true or false; it strengthened his government and so it was to be taught. Moreover, governments have now the power to get such *ersatz* truth widely accepted; they can monopolise press and radio, and say it is done to protect the people from their enemies. We have seen the totalitarian machines at work; truth is of no concern to them, so long as political ends are attained. The low view of man is false in itself and leads to falsehood in practice. Clearly

science, in so far as it represents the values of reason and of truth in particular, cannot be indifferent to such tendencies.

Our fundamental problem, then, is to recover a full view of the nature, situation and destiny of man; to rebuild the half-ruined ideals of our civilisation. This is the great current problem, reflected in almost any discussion on any serious subject. We must consider now the relevance of science to it. If our interpretation is sound, those people are wrong who say that it is the applications of science which are of paramount importance. Certainly technics will provide us with useful means of education, like printing, and with improvements in health and living conditions; but if the crisis is, as I am suggesting, concerned with beliefs about man and his situation, no amount of technical development can by itself solve the fundamental questions. The relevance of science to the problem is not, it seems, to be found solely in its applicability. Nor can we accept the view of those who say that science is the whole of rational knowledge, and that we could successfully apply the inductive method to every one of the problems of life. Such a belief cannot stand if one is aware that the inductive method does not prove its own presuppositions, or if one has considered the types of problem met with in metaphysics or moral philosophy. We shall not succeed if we reject at the outset the methods, evidence and conclusions of disciplines other than natural science.

The contribution of science to recovery from our crisis is to be sought, I would suggest, in its support of rational life and rational values. Scientific life is rational life in little; it could be used to show forth to a wide public the principles of rational life in general. This is the source of its relevance to the rediffusion of the principles implicit in our civilisation. Properly taught, science could make clear the primacy of truth to many who might otherwise not realise it; it could bring home the necessity of collecting and analysing data, of respecting the facts, of interpreting them synthetically; it could exemplify the interplay of thought and action, the primacy of ends and the choice of means to them. It could be exhibited as one example of rational method, admirably

adapted to a certain subject-matter viewed from a certain point of view; it could introduce the whole subject of the diverse adaptations of the general rational procedure of the mind interpreting evidence of various kinds to gain knowledge. It could be used to help to stimulate and keep alive curiosity and the sense of wonder at reality. The practice of science could be used also to introduce the principles of respect for other people and tolerance for their opinions, and the need for personal detachment. Natural science, then, could become a stiff bulwark in favour of respect for truth and for the human person. And it seems that it is in this role, as an influential representative of reason and as a type of rational method, that science is most relevant to the recovery of our society. It is not particular conclusions of science, nor applications of science, that can help us out of the mire, but a new realisation of the general outlook and principles that lie behind the spirit of science; a new approach that grasps through science the principles of rational life in general.

Such a use of the great prestige of science to-day would, however, fail unless science were pursued as part of a pattern of wider scope, and the limitations of its method recognised. For science will not give us the conceptions that we need in dealing with the fundamentals of life—the great conceptions of personality, justice, love, for instance, must be drawn from elsewhere; moreover, science gives us only part of the mental training for using them. Again, although science, given its appropriate setting, plays its part in developing both intellectual and moral virtues, it does not originate those virtues; it only supports them where they exist already. It favours an intellectual climate where persons are respected; but it does not create these values, it presupposes them. Professor A. D. Ritchie says in his book *Civilisation, Science and Religion*: 'The scientific spirit is tolerant, equalitarian, liberty-loving, and is so far humanitarian. All this is undeniable . . . (but) these moral qualities are preconditions for the pursuit of science, not products of science, except incidentally. . . . These virtues, belief in free discussion, tolerance and equal treatment of others, all spring from respect for persons and cannot exist

without that respect. . . . It is hardly an exaggeration to say that low moral standards of any kind might destroy the scientific tradition. Respect for truth and respect for persons as part of the general social tradition are needed for science to survive.'

The view that I am proposing, then, is briefly this. The major crisis of our time is the decline in our conception of man, in respect for truth and justice and the other values of Western culture. Science is concerned in the decline as an unwitting cause, for misinterpretations of science have been used to support facile materialisms, and misapplication of science has sharpened the crisis. It is concerned in solving the problem, not as a material panacea nor as the only valid method of gaining knowledge, but in so far as it is one version of rational method, and so favours respect for truth and for the human person and represents rational standards. By itself it cannot help us; but in association with other forms of knowledge it could play a useful part.

SCIENCE IN EDUCATION

This discussion leads us naturally to consider the place of science in general education, a topic which also brings to a focus several of the problems we have touched upon. A liberal general education is one that enables a young man or woman to form a reasonably complete and accurate picture of mankind and its situation and destiny, and to direct his or her life in accordance with that view. It must train the mind to answer the great questions concerned, and the will to make the difficult choices that rational living demands. An educated man should therefore have formed views on three great realities: nature, man and God. In the broadest terms, science deals largely with the first of these, literature, law and history with the second, theology with the third, and philosophy with all three. A view of nature is needed because our bodies are parts of it and at every turn we are in contact with it, whether our aim at the moment is understanding, or use, or enjoyment. An educated man should, moreover, have some grasp of the methods of his studies, as well as of their results;

he should be able to appreciate in a general way the kind of evidence used in each and the manner of its interpretation; for only thus will he be able to assess critically the content of what is presented to him as knowledge. In all this complex process—the training of the mind in rational methods of thought and the presentation of the data needed for a full and synoptic outlook, the training of the will and character—we should make use of the tradition of Western Christendom, with its three great strands: the intellectual curiosity and zest for truth and beauty that derive from Greek civilisation, the respect for justice and settled laws and stable institutions that we learned from Rome, and the new knowledge (especially on the value of the human person) and new life drawn from the revelation of Christ. In outline, then, these considerations define the aims of liberal education.

The contribution of science to such a liberal education, is or could be, threefold. It contributes to our understanding of nature; it can be made a school of rational method; and it trains the will by compelling a certain contact with 'brute fact and iron law'. To take these in order. In the first place, natural science contributes to our understanding of nature and therefore of man as part of nature, and of his material situation. The point needs no labouring. However, the mere teaching of science is not enough. We have to study not science alone, but nature through science; we have to appreciate not merely the beauty of the great scheme built up by science, but the beauty of that natural world which it partially describes. It is possible to study science for a decade and to have less understanding of nature than a ploughboy. Perhaps in our teaching the accent should be more on nature and less on science and scientists. Secondly, through science we can come to appreciate the inductive method that science uses. This should lead to respect for facts and an eagerness to interpret them; a realisation of the roles of observation and explanation, of the relation of evidence to conclusions; it should help to teach ready co-operation with others and respect for their work. It should besides prepare the mind for abstract studies of other kinds—philosophy, for example. The importance of this is that

familiarity with scientific method could lead on to an appreciation of rational method in general, and of the methods suitable in other fields. As an introduction to rational method, natural science (like every other discipline) has its peculiar advantages and disadvantages. The main advantages are as follows. The facts of science are concerned with visible and tangible changes; they are relatively simple and easily verified, and there is no serious doubt about most of them; thus there is less room than elsewhere for self-deception covered up by rhetoric, and the habit of close attention to concrete realities is easily acquired; moreover, manual dexterity is brought into play. The interpretations of the facts do not require mature wisdom or knowledge of the world, and can be tested by experiment. The subject-matter is remote from political turmoil, and does not impose the responsibilities that come with the study of metaphysics or morals or politics, yet it is of value in itself. The main disadvantage is that the method of science is an imperfect means of investigating matters that lie outside its scope, and leads to false conclusions if the attempt is made to apply it to them; so that its limitations ought to be explained as carefully as its merits. In science we take for granted the basic assumptions without which science would have no validity, we do not probe for ultimate reasons; we constantly (and often unconsciously) appeal to analogy as a sufficient argument; and we are perfectly willing to act upon unproved hypotheses. Within science all this is right and proper; but it would be lamentable if scientific education left the impression that basic assumptions should not be inquired into, that analogy is everywhere an adequate argument, or that in human affairs we can afford to act upon flimsy conjectures. At least as important as the understanding of scientific method is the realisation that it is only one version of rational method among many, and is unsuitable in the study of (for example) law, history, morals and politics, each of which has its own rational ways of handling and interpreting data, suited to its subject-matter and point of view. Finally, science can be used to some extent as a means of training the will. Scientific research can be a great school of patience and even of humility;

in the constant friction and effort and submission that experimental work entails, the scientist may find a discipline which is particularly relevant to modern western civilisation.

Natural science, then, is an essential element in a liberal education and there is strong justification for objecting, as apologists for 'scientific' education commonly do, to a purely literary education. (It is of interest that ancient and medieval education began with the science of their time; exclusive attention to literature seems to be a post-renaissance invention.) There is no justification, however, for making literature a scapegoat; if the curriculum is overweighted with science, the account of the human situation will be warped, the value of science in throwing light on other rational methods will be wasted, and the way will be open to all the misconceptions that follow from the idolatry of science.

It will be noticed that I am not putting forward a case for teaching science as the major element in an 'education for industrial society'. The reason is that I am contemplating a *liberal* education, one that will give an understanding of the human situation and the means to deal with it. Only after appreciating the great and permanent truths about human life should training for a particular (and possibly impermanent) environment begin. Otherwise a lamentably narrow outlook may result, a sort of cultural parochialism. Education has three functions with regard to the environment: to explain it, to supply what is lacking in it, and to resist influences in it which are harmful. The impression should not be left that the present industrial civilisation is built on ideal principles. Some words of Professor Max Born, written in 1941, sum the matter up: 'The essence of the question is contained in the eternal tale of Dr. Faustus, symbolising the soul of man, wrestling for truth and beauty, and of Mephistopheles, the roguish devil, offering him a worldly paradise which ends in hell. We have the choice of teaching science as natural philosophy, framed into a general Faustian education, or as the creator of wealth and power, with the alternative of such wholesale destruction as we are witnessing to-day.'

It is a far cry from the ideals we have outlined to the specialised

technical training that now too often passes for a scientist's education. The claims of vocational training cannot be neglected, but for most students they are overwhelming. To the narrow specialist, every rational method other than the inductive becomes unintelligible, and the content of every discipline other than science becomes unfamiliar. Literature is tedious, metaphysics plays with words, history is 'bunk'. But if scientists are to serve our civilisation they must understand its literary and artistic and philosophical and religious traditions. Therefore I make no apology for enunciating the remote ideals; without them there will be no progress.

CONCLUSION

Science is distinct from technology, and the social problems raised by it are quite different. The social function of science is twofold: to represent rational values and to supply techniques for legitimate material ends. Science is concerned in the major crisis of our time—the decline in our conception of man—because the value of truth is endangered, and because the crisis is partly due to the belief that science is the sole means of reaching truth, so that a more accurate view of science would remove one source of low views of the nature of man. Science can help to a solution of the crisis—the recovery of a true view of man—in so far as it favours respect for truth and for the human person. Scientists should make it their business to uphold rational values, and at the same time resist attempts to extend scientific method to fields where it is inappropriate and can only lead to disastrous conclusions. Science should find a place in a liberal education, which is incomplete without a view of nature; the deficiencies of its method can be supplied by teaching it in association with other disciplines.

CHAPTER XI

Conclusion

SCIENCE AND ITS VALUES

In this book I have tried to develop a constructive view of the place of natural science in thought and in human life. Science examines nature from a certain point of view, by the inductive method; the several branches of science (physical, biological, psychological) have each their own special field and special modification of the method. Scientists can ignore, if they wish to avoid philosophical problems, the question of the relation of science to nature; science is then autonomous and consists simply of a unified scheme of data, laws and theories. But from a realist point of view the laws and theories are an approach to truth; they are 'significant of' nature. Thus besides the beauty of its own logical theoretical scheme, science reveals harmonies in the working of nature, and so contributes to the appreciation of its beauty. The way in which physics is 'significant of' inanimate nature is rather enigmatic; it describes nature in terms of mathematical relations, and supplements these equations with analogies. But, at all events, natural science is an approach to truth by a rational method suited to the subject-matter and to the aspect under which it is viewed. It is not the sole version of rational method, but it is one that is relatively easy to grasp. As such it offers an example that could be used as a springboard in illustrating some of the characteristics of any rational approach to experience. Thus, though not itself wisdom, it can contribute to a wisdom based on a wider survey of things. Science and its technical application can both be integrated into the pattern of the good life; science forms an integral part of the good life for a scientist, and the applicability of science can be turned to good account. Potentially, then (whatever we may think of it in practice), natural science is an ally of wisdom and good living.

SCIENCE AND OTHER DISCIPLINES

Scientific life (unless we restrict ourselves to the autonomy of science in its narrowest sense) depends at every turn on disciplines other than science. The scientific method itself presupposes the metaphysical principle that there is order in nature. Any treatment of its value rests on metaphysical presuppositions. Any account of its place in life depends on ethical propositions which it must assume. Science cannot establish the philosophical propositions of which it must make use. A different viewpoint and a different method are required in metaphysics and ethics; the method is not inductive, but reflective. The inductive method is not suited to the discovery of philosophical principles. Most scientists take for granted their metaphysical assumptions, but they are none the less necessary logically to the conclusions of science.

It follows from our account of the method of science that it is not the sole source of truth; nor is it a sufficient source, since it cannot deal with the metaphysical and moral topics that are of greatest importance to man. We cannot base metaphysics or ethics on scientific method, nor on particular conclusions of science, though some have tried to do so. We cannot settle the nature and destiny of man by reference to natural science, either in its present state or in any conceivable future state, though some have thought it possible. It follows also that the method and aims of science are both different from those of technology, which is concerned with the control of nature rather than its understanding, and presents quite different problems from science.

SHORTCOMINGS OF SOME MODERN THOUGHT

If this account be true, we must conclude that much of what passes for modern thought has seriously misconceived the scope of science and over-estimated its capabilities for discovering truth. Anyone acquainted with the beliefs current in this century is aware that the real or imagined 'implications of science' have

been a major influence upon them. Anyone who reads an exposition of the resulting notions must be impressed with the responsibility that hangs on those who present science to the public. Anyone with a logical mind will see that the alleged conclusions of the schools of psychological materialism (for instance) do not follow from the premisses adduced. The belief that physics has a bearing on the freedom of the will, that biology can pronounce on the human soul, that empirical psychology shows that men are not masters of their apparently reasonable actions—these beliefs have no support whatever in the scientific data, because those data were not obtained from the relevant point of view. Thus in physics one omits from the start everything characteristic of human beings, and it is not surprising that the results have nothing to do with the question of the freedom of the will. All the data of science can in fact be interpreted in terms of a realist philosophy that borrows no conclusions from natural science.

We must conclude also that much current thought about science itself has a false orientation. Many people think of science merely as a source of techniques, and so neglect science itself which is a source of truth. They neglect the social function of science itself—the upholding of rational values—and concentrate on the usefulness of its applications. Some accounts of the history of science have been given a curious twist by people of this way of thinking; they present science as justified by, and dependent on, its contribution to material welfare, and so neglect the important questions of the relations of science to the other intellectual currents at a given time. Education in science, again, is too often conceived merely as instruction in the techniques useful to an industrial society, rather than as a part of the study of nature necessary to a liberal upbringing.

Thus if we misconceive the method of science we are led into grave errors not only about science itself, but about metaphysics, about ethics, about politics, about history, and about education. A small mistake at the beginning leads to a whole crop of disastrous falsehoods at the end. In the crisis of our time we cannot afford such errors. We need clarity of thought and cannot afford such

confusions; we need a wide synthesis of knowledge and cannot afford such narrow views of the scope of reason.

NEED FOR A SYNTHETIC VIEW OF RATIONAL METHODS

So far from being an ideal to which metaphysicians, moralists and historians (for example) should strive to approximate their methods, the method of natural science is quite inappropriate if we want results recognisable as metaphysical or ethical or historical. If we try to reduce all these modes of knowledge to natural science, we shall only achieve a bogus unity, a *Gleichshaltung* in which metaphysics and morals and history will have lost their souls. We must let each of them follow the method suitable to its subject-matter and point of view, and then unify their results in the light of a comparative study of their methods and their presuppositions.

A synthetic view of methods is perhaps almost as desirable as a synthetic view of results. A synthesis is essentially a personal possession, an order achieved by a person among his beliefs; no paper scheme, however complete and harmonious, has the same value as a synthesis of one's personal knowledge; and for this one needs a survey of methods, and a bird's-eye view of the kind of knowledge that can be obtained by each. A comparison of methods, then, may be even more useful, in the present state of thought, than a comparison of results. It seems, indeed, that one of the most urgent needs of contemporary intellectual life is a clear understanding of the relations and differences between the methods of natural science, mathematics, philosophy, history, literature and theology. It is time to develop the comparative study of rational methods. Work in this field has been piecemeal and scattered. We need a survey that will show with precision how the diverse methods of the various rational disciplines are all versions of the general method of reason working on experience, and yet are all legitimately different. A constructive account such as this could do much to ease the intellectual malaise of our time, which cries out not only for clarity of thought but for synoptic views.

FUNDAMENTAL ERRORS AND THE ULTIMATE SYNTHESIS

We know the consequences of the intellectual chaos of our time. We are familiar with the facile systems erected on partial views and limited aspects of experience; the appeals to science as a by-pass round the laborious reasoning of philosophy; the clutching at scientific straws to save beliefs that should be defended by ethics or metaphysics; the uncertainties about values, about immortality, about the existence and relevance of God. We see the results of this confusion of voices in the sapping of our standards of respect for truth, justice and the human person.

Our troubles are not fundamentally political; they are ethical, metaphysical, and ultimately theological. They are concerned with the good life for man, therefore with the nature and destiny of man. This raises problems that cannot, in my view, be solved without deciding whether it is possible for human and divine to meet, whether the gap between man and God can be bridged (as Christians hold it can). But without tackling this question, which lies beyond the scope of this book, we can recognise some essential conditions for any solution. We must insist on the accurate discrimination of methods, and refuse to countenance the extrapolation of science beyond its proper limits. We must include ethics and metaphysics in our synthesis of knowledge, and decline to replace them by pseudo-scientific substitutes. We must adopt the higher view of man's potentialities, rather than any of the narrow materialist views, both because it is true and because the consequences of denying it are disastrous. Only then may we hope to work towards a new synthesis, acceptable to a science-conscious era; that synthesis for lack of which so much effort and devotion and love are at present dissipated and unfruitful.

Appendix

The 'Cosmological' Argument for the Existence of a First Cause

SKETCH OF THE ARGUMENT

Here and there in this book we have noted that many of the problems that beset us require an answer to the question whether a first cause exists or not.[1] We must now try to sketch and to assess an answer. The argument continues straight on from the discussion ending on p. 112 (Chapter VII). We had there given some account of causality, and remarked that reflection on human activities and human nature carries us farthest in this discussion; we are aware of ourselves as agents, efficient causes of changes in ourselves and other beings, and reflection on such data gives us some insight into the necessary conditions for any change. We noted briefly that a similar investigation into the necessary conditions for the *existence* of anything had been carried out. We can now give in briefest outline the core of this argument—taking again our knowledge of our own human operations as the most accessible data.[2]

Suppose that I want to consider the necessary conditions for *my existence now.* Not the conditions for any changes in me; nor the conditions for my coming into existence; but for my existing now. I am a being with a certain nature, which, with its potentialities and limitations, I can appreciate in general terms. Does this nature account for my existence—is there anything in this nature that makes it necessary that I should exist? Is existence part of the definition of human nature? Am I a sufficient cause for my own existence? Am I self-existent, the source of my own being? We need to reflect on the questions, and on human nature, to see the answers. There is nothing in my nature that necessitates that I should exist; existence is not a part of my nature; the definition of human nature does not include necessary existence. My nature and my existence are distinct. My powers of making and acting (cf. p. 111) are inadequate even to hold in existence the least material object, let alone myself; I am not the source of my being, not the root cause of myself; I do not exist 'under my own steam'. There would be no contradiction and nothing impossible in

[1] The term 'first cause' denotes God in so far as known to metaphysics, omitting consideration of revelation.

[2] For fuller expositions the reader is referred to the Bibliography.

my not existing. Analysis of my being from a metaphysical point of view shows that my nature does not account for my existence, that I am not self-existent and do not give existence to myself. The only analysis that can be given of my existence is that I am nature-plus-existence. I must *receive* existence, from some cause other than myself. I am a nature that has received existence. I am contingent, not absolute; dependent, not self-existent. My existence requires an independent cause, one capable of holding me in existence.

Is this cause self-existent, or does it receive existence as I do? If it receives existence, it still requires a further cause, of a higher order than itself, to hold it in existence. And as the ultimate first cause there must be a self-existent being which gives existence to everything else; whose nature includes existence and which exists necessarily, and can cause the existence of all finite and contingent things. There can be no question here of an infinite series analogous to those of mathematics, or of a series of successive events infinite in time. There is no similarity between such series and the series we are considering, namely a set of causes of different orders, essentially subordinated each to the next. (A closer analogy, though a very rough one, would be the series typescript-typist-author; the typescript depends on a typist and the typist depends on an author; the author is a cause of a higher order than the typist.) A series of essentially subordinated causes must culminate in a first cause, which gives being to all the others; for otherwise we should still have to ask the question, 'Why, ultimately, does it exist?'

Let us restate the argument. We know that there are beings, and of the nature of some of them, notably ourselves, we have quite accurate knowledge. We know too that at least some beings, and notably ourselves, are contingent—their nature is not such that they exist necessarily, it does not by itself account for their existence. They must therefore receive existence from some cause competent to produce it. This requires ultimately a being who is self-existent and the cause of all existence—who is the first cause of all beings.

More briefly, the argument is sometimes stated in a form reminiscent of a syllogism. Every being either exists of itself, or depends for its existence on something else. But we know of beings (such as ourselves) whose natures do not necessitate their existence, and which therefore depend for their existence on something else. Therefore that something else exists; it exists of itself and all other beings depend upon it. This is not really a syllogism, and it would be a mistake to force the argument into such a form if it were to obscure the real structure of the demonstration; it is, however, one way in which the argument can be

summarised. More briefly still, it is sometimes said: Contingent beings exist, therefore a first cause exists. This again is not demonstrative, because the words 'contingent' and 'therefore' need elucidating, and the elucidation constitutes the real demonstration; we have merely put up a peg on which to hang the discussion. We shall discuss later the exact status of the argument.

So far we have argued for a self-existent being, which is the first cause of the existence of all other beings. The evidence is that there is nothing in the nature of these other beings (such as ourselves) that necessitates their existence; they are contingent, dependent, changeable. Extension of this line of thought leads to the conclusion that the self-existent being is also the first cause of all change; it is a creator, in the sense both of causing the world to begin and of causing it to continue in existence; further, it is distinct from the world. And we can enlarge our conclusions again if we consider some other characteristics of finite things. For instance, we reflect that things differ in their degrees of beauty and goodness; it is certain that there are degrees of perfection. There is first an order among beings of different natures; for example, a man is by nature capable of attainments impossible to a bird, and a bird can do things impossible to a stone but natural to a living organism. Also there is an order among beings of a given nature; some men are wiser than others, some fulfil more perfectly than others the potentialities of human nature. Anyone who compares, say, Socrates with Nero can see which of the two men was more advanced in the pursuit of truth and goodness; and between such limits there are innumerable degrees. Evidently then a man, say Mr. X, does not possess perfect goodness. Mr. X is not goodness itself. He is not the source of goodness. He *participates* in goodness; the goodness that he has is received. The first cause gives not only existence but all wisdom and goodness and beauty as well. If then we consider the degrees of perfection of things, the first cause appears as supreme perfection.

Again we can consider the ends attainable by finite beings. Suppose as an example we take the capabilities, the potentialities, of a human being. Since I have a human nature—rational as well as animal—I am evidently able (so far as my nature is concerned) to develop in certain directions laid down by that nature, and not others. I cannot grow to be five miles high, or attain a temperature of two thousand degrees, or understand all the laws of biology by intuition, or give rise to acorns like an oak tree. My nature is not like that. But I can (in principle) seek truth and so attempt to become wiser; I can seek good and attempt to become better. My nature has certain ends implicit in it, certain ways of internal development, a certain intrinsic finality. I did not

choose these ends for myself; they are given to me; I received them, along with my existence as a being of a particular nature; and I cannot get rid of them, even if I refuse to live in accordance with them. So it is with an organism; a foal does not develop into a wrist-watch or an equation, but into a horse; it does not choose this particular finality, this direction of its development (in normal conditions), but receives it, along with its existence as a being of a particular nature. Thus the first cause on which our existence depends is also responsible for the possibilities of the development of things; it is the law-giver and the designer[1].

The first cause, then, is manifested, through finite things, as creator, self-existent, supreme perfection, and designer. Much can be deduced from these characteristics, for which the reader is referred to the several excellent works available. I have merely tried to sketch the argument, not to give it in its full and rigorous form. My object is to suggest the kind of evidence that is used in such an argument, and to indicate that natural science is irrelevant to it.

SOME OBJECTIONS TO THE ARGUMENT FOR A FIRST CAUSE

It is time to consider various objections to this argument. We have already noted the mathematician's argument that a series may be infinite, the physicist's argument that a causal sequence may extend infinitely backwards in time, and the irrelevance of these objections. Indeed we may say generally that physics is irrelevant to this matter, because we are dealing with causes, as such, not with the laws of their behaviour; further, we are dealing with causes of existence, not merely with the conditions of material changes. A very important characteristic of the argument is that at no point in it do we rely on empirical generalisation. We are not generalising about the behaviour of things; we do not say 'I observe that *A* requires a cause for its existence, *B* requires a cause for its existence . . . therefore everything requires a cause for its existence'. We do not need to make any statement about a particular class of things. One single example of a contingent being is enough, if properly understood and interpreted. Certainly the argument is based on experience; we shall not recognise contingency, nor interpret it correctly, without a mass of experience; but we are not putting forward any scientific generalisation. The point of view and the method are not those of natural science, but those of metaphysics, which we have tried to characterise in Chapter VII.

[1] We must not confuse this conception with that of the 'argument from design' in the so-called natural theology represented by Paley; the argument is completely different, since it is concerned with intrinsic finality and not with the relations between different beings.

The real objections, then, must be philosophical ones. One such major objection is presented by those who think we cannot have any knowledge of the real nature of anything, even of ourselves; they object to the apparent *naïveté* of our epistemology. To this objection the treatments of Chapters V and VII are, I hope, sufficient reply. The other main objection is raised by those who say that since our experience is confined to finite things, we can know nothing whatever about an infinite being, at least by reason. But this is only partly true. We cannot fully comprehend the nature of the first cause, but that does not imply that we have no knowledge of it at all. Even if we cannot intuit *what* it is, we can know *that* it is, arguing from effects to cause. We can also know what the first cause is not; it is not contingent, limited, imperfect; most of our philosophical knowledge of it is confessedly of this negative kind. We can even know, in a remote way, what it is like, by means of transcendental characteristics such as truth and beauty. These are peculiar attributes because they belong to all beings, but in different ways; a good poem, a good elephant, and a good man are all good, but in different ways, proportionate to their natures. So also the first cause is good, in a way proportionate to its nature, and though we cannot comprehend this to the full it is decidedly positive knowledge. We are here at the threshold of a discussion of analogical terms in philosophy, for which the reader must again be referred to fuller works; here it must be enough to indicate that philosophers who use this argument are not thereby claiming an excessive familiarity with what must obviously be hidden from philosophical reflection.

STATUS OF THE ARGUMENT FOR A FIRST CAUSE

We have still to assess the status of the argument; the extent and nature of the evidence and the validity of the interpretation, and hence the reliability of the conclusion. We may start by stating what the argument is not. It is not a proof of the type characteristic of mathematics, in which one assumes certain premisses or axioms and proceeds to derive conclusions by pure deduction; it does not rest solely upon formal logic. On the contrary, it is very much concerned with the truth of its premisses; if they could not be established, the argument would fail. But, on the other hand, the argument does not depend upon empirical generalisations, nor on analogy (in the sense used in the theory of induction); it does not follow the method of natural science. Again, the conclusion that the first cause exists is not a deduction from premisses whose truth is claimed to be self-evident without reference to experience; it is not an *a priori* argument in this

sense. In fact it is not a deduction at all, in the strict sense; it is rather the conclusion of an analysis. The evidence for the conclusion is the agreement with experience of the view that we know at least one contingent being, and the contradictions in experience to which we are led by denial of this view. Although it may appear at first sight that there is nothing self-contradictory in saying 'I am the sole cause of my existence', or 'I am not the sole cause of my existence, nor do I receive existence—I just happen'; yet the statements are self-contradictory when we analyse the meanings of 'I' and 'existence', for the only analysis that agrees with experience is that I am contingent, dependent, caused. A man who tries to assume that such sentences express credible statements will soon be led to thoughts or actions that deny them; he is certain to admit ultimately in some way that he depends on some other cause than himself. In practice, too, everyone admits that the existence of beings other than himself requires explanation. One is reminded of the story of the well-known agnostic visiting a factory, who, observing an ingenious machine, inquired who designed it, and was told, 'Oh, no one designed it, sir, it just happened'.

The 'cosmological' argument is put forward as an analysis of finite beings—it claims that we can verify that, regarded metaphysically, they are composite, that their natures and their existence are distinct, that they receive existence from the first cause. It implies an invitation to look at the objects of experience in a certain way, and to see whether that way does not make the best sense of experience. It is suggested that finite beings lean on infinite being, and that the results are manifest; that such an analysis of the beings that we know (and in particular ourselves) is necessary if we are to have an interpretation or an explanation of the whole of experience, an insight into the reality that experience manifests to us. To verify this we have to look and see —we have to reflect upon things from this point of view and see whether the analysis is successful. Reasoning alone will get us nowhere; it is a grasp of reality that is needed. And this is the great difficulty in 'demonstrating' the existence of the first cause; you cannot compel a man to look. If he will not look (and many find it difficult to look from a metaphysical angle), there is no knock-down argument, of the type '*P* is self-evidently true *a priori*; but *P* implies *Q*; therefore *Q* is true'. The demonstration relies ultimately upon metaphysical intuition (which is nearly related to common sense) helped out with examples. The essential stage in coming to see the conclusion lies not in assenting to logical processes, but in coming to see that the analysis of finite real things is true—in looking at reality until, in the words of a modern author, it breaks into finite and infinite. 'If there were no

first cause, there could be no finite beings'—that is not to be proved by any inductive generalisation; it is simply an analysis of reality that claims assent because with it we enter upon a world-view that is verified at every turn, whereas without it we cannot make sense of the data of experience. If events just happen, and things just are, we can understand nothing fundamentally; if things and events depend ultimately on the first cause, we can understand all the hard facts to which the argument above has appealed. And this is the sort of demonstration expected in metaphysics. There can be no purely logical compulsion about it; it compels assent only if we inspect the evidence from the appropriate point of view, and actively interpret it.

The evidence for the conclusion includes the agreement of a whole coherent world-view with the facts. Granted that sort of world-view —granted some such view of change and development, causality, the human person, and the rest, as that which I have briefly suggested, following philosophers like Aristotle, Aquinas, and in modern times Maritain and Gilson—the existence of the first cause must be admitted. The complete world-view, or type of world-view, entailing the conclusion that there is a first cause, has to be considered; as against types of world-view that are agnostic or pragmatic or phenomenalist in their theory of knowledge, or mechanist or materialist or idealist in their metaphysics. It is not, then, a single argument, but a whole metaphysic, that has to be examined; if we deny the existence of a first cause we deny also that metaphysic, which would be self-contradictory without it. But could we reject that metaphysic, or type of metaphysic, without doing violence to experience? Once appreciated, the evidence excludes the possibility of denying the statement 'the first cause exists'; the conclusion is rationally certain.

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